A

DISCOVRSE

OF THE VARIATION

of the Compaſſe, or

Magneticall

Needle.

Wherein is Mathemati-

cally shewed, the manner of the obſeruation, effects, and application thereof, made by *W. B.*

And is to bee annexed to the newe Attractiue of *R. N.*

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E. Allde for Hugh Aſtley,

dwelling at S. Magnus Corner. 1596.

To the trauailers, Sea-men, and Mariners of England.

HAuing of late gentle (Reader) receiued from the expert Artificer, Robert Normã, his booke entituled: The new Attractiue (who of the great good wil & affection he beareth, hath attribuited in his dedication, that which I acknowledg not to be due) in the which amõgſt other diuers vertues & properties of he Magnes or Loadſtõe, he entreateth of the declining of the Needle touched therwith, from the plain of the Horizon, (a matter neuer before found or writtẽ of by any.) For the further behoue & benifite of all trauailers and Sea-men, I took occaſiõ to enlarge the ſame with this diſcourſe of the Variation or the Compaſſe, wherein I haue handled the whole variety of that ſubiect, both practically, and Mathimatically, to the end I might partly ſatisfie both the vulgar and alſo the learned ſort. For knowing the variation of the Compaſſe, to be the cauſe of many errors and imperfectiõs in Nauigation, and perceiuing that al thoſe that haue as yet gon about to giue rules in that art, haue left this (being a principall point, and euen the ground of all the reſt) vntouched, or at leaſt ſo ſlightly handled the ſame, that little or no benefite could be gathered thereby: I haue heere ſet downe the ſundry waies to obſerue the ſame at all times & places, that the inconuenience being known, might be cõſidered off, and auoided Wherin, although my chiefeſt intent hath been to pleaſure thoſe that ſhal haue occaſion to put the thing in practiſe by their owne trauaile and experience, yet becauſe ſome of the rules are deducted from the

fountaines of the Methematical Sciences, and wrought by the Doctrine of Signes and Triangles, which maye seeme straunge in our English tongue, & wherwith few Sea-men are yet acquainted, I may seeme to haue missed of my first good meaning, but I wold wish thē to choose that which is plain and conformable to their capacities, & make their profit thereof, and for the rest vnderstand, that of such obseruations as they themselues cannot presently apply to the purpose, by others, that are throughly instructed in these Mathematical supputations, or by themselues when they shal attaine to the knowledge therof, may be inferred such effectuall matter, as is by these rules & precepts promised. Wherfore I would haue al Sea-mē to vse such diligence in their trauails, that no opportunity be omitted whē, or wher any obseruatiō may be made, either for the variatiō, or latitude of places, or any other necessary point incident to Nauigation, & therof to keep continuall notes & memorial. For these obseruations there needeth not many troublesome instruments, onely for the variation, the new instrument in the end of this treatise I preferre before all other. And for eleuations, a plaine Astrolobe exactly made, & a crosse staffe are sufficiēt. (The Globe wer also a very good & necessary instrument: for besides many pleasant conclusions that may be tried by it, it doth lighten very much the conceits: for vnderstanding diuers importāt points, but it is too troublesōe (or otherwise not fit for euery Marriner) to be caried to the sea. Vnto the which may be added the Topographical instrumēt, for taking of dislāces, & making descriptions vpō the land. With these instruments, and the sailing compas and Marine plate, (which are alwaies to be vnderstood the principal, and most necessarie instruments for Nauigatiō, for by them only, any voyage may be made, but without them no Nauigation can be performed,) the whole worlde may be trauailed, discouered, and discribed. These are sufficient for a perfecte Mariner, and more then these wer superfluous, only the running glasses, leads, lines, and

and ſuch like appendances, of other excepted.

But to haue all theſe inſtruments, and not to vnderſtand the grounds how to vſe thē, were a great vanity. Therfore I wiſh al ſea-men & trauailers, that deſire to be cunning in their profeſsiō, firſt to ſeek knowledge in Arithmatike, & Geomatry, which are the groundes of all ſciences, and certain arts, of the which ther is written in out Engliſh tong, ſufficient for an induſtrious & willing minde to attaine to great perfection: whereby hee may not onely iudge of Inſtruments, Rules, & precepts giuen by other, but alſo be able to correct them, & to deuiſe new of himſelf. And this not onely in Nauigation, but in al Mechanical Sciences. As by the ſtudious practiſe and exerciſe in theſe Arts, haue attained to rare & ſingular knowledge: In Architecture, Vitruuius the Romain, in painting that famous Germain Albertus Durerus: and in building of ſhips, Mathew Baker our country-mā: & others in other faculties, as they haue bene moſt ſkilfull herein, ſo haue they excelled. Hauing theſe helps & groundes, with the inſtruments before ſpecifie[d] a Mariner may be able to make deſcriptiō in plat of the coaſts and countries, & of the banks, rocks, & ſholds in the ſea, with the depths, & other neceſſarie notes obſerued in his owne trauails, perticulerly & effectually according vnto the truth (which is the chiefeſt part required in a perfect Mariner.) And not be alwaies tied to the reportes of other, or to the Portugale, or ſpaniſh Marin plats, which are made by the card-maker of thoſe countries, men that are no trauailers themſelues, but doe al things therein, by information, & vppon the credite of others, which onely commit to memory the forme & maner of the Sea coaſts, with making ſome few notes of the lying of one place frō another, which can neuer be ſo perfect, as the deſcriptions that are made vpō the preſent ſight and view of places, albeit he be neuer ſo skilfull and cunning, that ſhal ſo carrie the ſame by memorie, how much les thē by the vnskilful: by this meās ꝑ card makers ſet down they know not what,

as maye appeare by the descriptions of their owne coastes, which are verie grosly and vnperfectly done, whereas the marin Plats ought to be described by such as can giue reason, & shew obseruation of euery perticularitie contained in the same, as well for the latitude of places, as the lying by the compasse of the Capes, Head-landes, pointes, Ilandes, Baies, Rocks, Sholds, &c. one from an other, and the distances between them. The errours of those descriptiõs, I may not attribute to the card-makers, but to the vnskilful seamen of those countries, for if they were otherwise, as they haue been accounted the most skilfull of the world, those errors could not haue cõtinued as they do: tru it is, that for their great trauails, they haue been worthily famous aboue all other nations, till now at length our Country-man Sir Frances Drake, for valarous attempt, prudent proceedings & fortunat performing his voyage about the world, is not onely become equall to any of them that liue, but in fame farre surmounteth them all. But those card-makers, and al other that collecte and gather Hydrographicall, and Geographical descriptions of other mens trauails or reports: as their paines may be great, and deserue due comendations, so their doings may bring cõmoditie diuersly. And in this behalf Abrahamus Ortelius in his Theatrum, hath deserued immortall praise, for collecting together, and reducing into one commodious volume, the dyuerse Plats and descriptions, made by diuers & sundry men. But amongst al those that haue made Geographical descriptions, I cãnot a little meruel at Gulielmus Postellus, who being a famous learned man, a great trauailer and Cosmographer, & deane of the Kinges professors in the Vniuersity of Paris, in his vniuersal Map, An. 1580 besides that, it is generally handled after suche a grose and confused manner, that it might seeme rather to haue come from some rude vnskilfull, thẽ from him so famous a Doctor, hath also in the imagined Countries about the Norrh *Pole*, so corrupted it with his fond dreams, & fãtastical inscriptions, attributing to those

suppo-

ſuppoſed lands, diuers people, as the Georgians & Hyperborians, and aſsigning there to bee the higheſt hilles of the world, and the people dwelling on them, to haue the cōtinuall light of the Sun, Sueta, Zemlia found by the engliſhmen, An. 1550. the holy Land, the place of the chiefeſt felicity, the Hiperboreā fields, & therfore the felicity of the Moluccas, with many other ridiculous abſurdities: That by the groſe errors of this learned man in theſe matters, I am taught, that whatſoeuer fame goeth, or opinio is conceiued of any man for profound learning, and ſmooth deliuering of their conceits, or whatſoeuer great promiſes are by theſelues made in theſe artes, to iugde of thē according to the works that come frō thē, & not otherwiſe to be deceiued.

For auoiding prolixitie in this my Preface to ſo ſmall a volume, I referre thee gentle Reader, to the worke it ſelfe. Yet by the way it ſhall not be amiſſe, that I cōmend vnto you the Table of the Suns declinatiō (or Regiment) made by R.N. which is calculated for the preſent time, & differeth not from the truth in any place aboue one minute, wheras in al other hetherto made & extant, there are great errors. Therefore, ſuch as otherwiſe cannot from time to time calculate their declinatiōs, according to ỹ place of the Sunne to be giuen by the Ephemerides, and table of declination of Reinholdus, may boldly vſe this regiment for 20 yeares, without any ſenſible error. And ſo wiſhing my trauailes in this treatiſe, may do ſuch good as I meant, I commit the ſame to your gentle conſtructions, & your ſelues to the Almightie. At Limehouſe the 26. of September.

Anno. 1581.

William Borough.

¶ A Table of the chapters contained in the Treatise. following of the variation of the Compass

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The seuenth

The seuenth chapter.

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¶ Of the Variation of the Compasse or magneticall Needle.

Chapter. 1.

THE Variation of the Needle or Compasse, is properly the Arke of the Horizon contained betweene the true Meridian of any place, & the Magneticall Meridian of the same, and is denominated to bee Easterly, or Westerly, according to the position of the Magneticall Meridian to the Eastwardes or Westwardes of the true Meridian: And may be accounted either from the North parte, or the south parte thereof, but vpon opposite points it hath contrary denominations.

The Magneticall Meridian, is to be vnderstood a great circle passing by the Zenith and the Pole of the Magnes, deuiding the Horizon into two equall parts crossing the same at opposite points: which intersections or crossinges, are shewed by the Needle, or wiers of the Compas, touched with the Magnes or the Loadstone.

The Azimuth of the Sunne is a great circle, passing by the Zenith, and the true place of the Sunne: crossing the Horizon at right angles in opposite points, and diuiding the same into two equall partes, and it is saide to bee giuen when the distaunce thereof from the true Meridian is knowne.

The Azimuth of the Sunne vpon equall eleuations in forenoone or afternoone, haue equall distaunces from the true Meridian, so that the middle point of the whole difference of any two Azimuths obserued vpon equal eleuations in forenoone or afternoone, is the true Meridian.

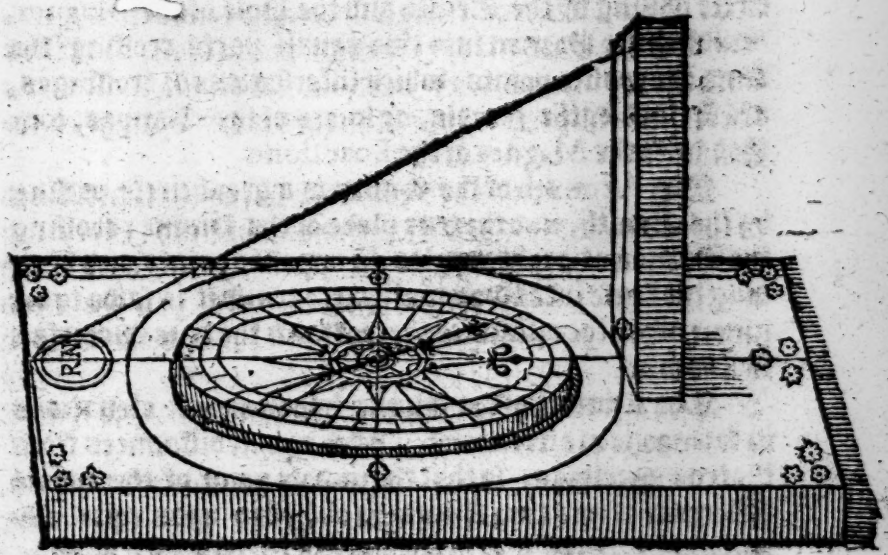
This difference of Azimuths, is found vpon the Instrument

ment of Variation, by adding together the Variations of the suns shadowe, at equal eleuations in the forenoone and afternoone. The halfe whereof is the distaunce of the Azimuths from the true Meridian: the which compared with either of the same Variations of the sunnes shadowe, the difference shall bee the Variation of the Needle, from the trus Meridian.

Or els subtracting the lesser variation of the Sunnes shadowe, from the greater (at equall eleuations) the halfe of the remainer shall bee the true Variation of the Needle from the Meridian.

But the Azimuth of the Sunne being otherwise giuen, and the Variation of the shadow likewise giuen, the difference betweene them, is the variation of the Needle.

The Variation of the Sunnes shadow, I call the Horizontall distaunce betweene the Azimuth of the Sunne, and the Magneticall circle, which are represented in the Instrument, by the shadowe of the line, and the Needle.



The

Of the Variation
The second Chapter.

The manner how to vse the instrument of Variation.

First you must place the instrument vpon some stoole, or other thing that is flat, so as it may stand leuell, & the Plummet in the Standerd which is placed at the North end of the fixed Flie, may fall perpendicularly, with the line in the same Standard.

You must haue regard that in remouing the instrument to the sunne as hee goeth about, it may alwayes stande leuell as afore said.

You are then to consider, that the string that reacheth from the south parte of the Instrument to the top of the standard, is the chiefest string to giue the sunnes shadowe which must be so directed by turning the Instrumentes South side to the Sunne wards, that the shadowe of the same maye fall directly longst vppon the lyne of south and North in the fixed Flye, for it ought not to crosse or decline from the same lyne in any part, but if it do, you must seeke to reforme it, by setting the standard more vpright, or remouing it at the south end.

Then must you also see, that the string that is fastned to the hoope of Brasse that inuironeth the fixed Flye, may bee so placed that it agree Iustly with the shadowe of the former lyne, and the lyne of south and North in the fixed Flie, in such sort that both the shadowes may be as it were hidden in the said line of the Flie: which you may do aptly by turning the said hoope, and remouing the same lyne at either side of it, as you shall see cause.

The Instrument being duly placed in forme afore said, it differs nothing from the Compasse of Variation, but onely in this point, that whereas the Flie of the compasse of Variation, is so turned by vertue of the Magneticall wiers,

wiers, that the Northy point thereof dooth shewe the Pole of the Magnes, or line of Variation. In this Instrument, the Northy point of the Needle dooth supplie that, which the Northy point of the compasse should doo. And the Northy point of the Flie which is fixed in the bottome of the Instrument, dooth alwaies aunswere to the shadowe that the Sunne giueth.

The third Chapter.

How to finde the variation of the Needle or Compas at any place, the eleuation of the Pole, and scituation of the Meridian vnknowne.

When you would obserue the variation in any place, you must begin in the forenoone the sooner the better, and the more effectuall may your obseruations bee, doe thus. Take your Astrolobe, and obserue dulye the height of the Sunne, for your more ease it shall be best for you to note the same, when it agreeth to be iust vpon a degree, without any consideration of minuts, or fractions, and at the instant of the same height, turne your instrument to the Sunne, so as the shadowe of the lines may fall iustly vppon the line of the south and northy in the fixed Flie.

Then, when the Needle doth stand, looke directly ouer the Northy point of the Needle, what degree and fraction, (if there be any) doth answer vnto ỹ same in the fixed flie, that is to say, howe many degrees it is from the Northy of the fixed Flie, which you shall note diligently, and maye say, that so many degrees, &c. is the variation of the Suns shadow from the Northy, as the Northy point of the Fly is from the Northy point of the Needle, either Eastwards or Westwards as you shall finde the same. Thus may you obserue diuers times, vpon seuerall degrees of the Suns

eleuation

eleuation. And like as you do in the forenoone, so must you also obserue the Sunnes eleuation in the afternoone vpon the same degrée of height, and with the same side of the Astrolobe and Index turned towardes the sunne, as it was in the forenoone (for auoiding of errour that may bee in the Instrument) noting at euery height, what you finde the variation. And when the Sunne commeth to the Meridian, it shall be good that you exactly obserue his eleuation vpon the same, for knowing the true latitude of the place: all which you shall set downe in forme following.

Example.

In Limehouse the sixteenth of October. Anno. 1580.

Forenoone.			Afternoone.				
Eleuation of the Sunne.	Variation of the shadowe frō the North of the Needle to the Westwards.		Eleuation of the Sunne.	Variation of the shadowe frō the North of the Needle to the Eastwards.		Variation of the Needle frō the Pole or Axes.	
Deg.	Deg.	Min.	Deg.	D.	M.	D.	M.
17	52	35	17	30	0	11	17½
18	50	8	18	27	45	11	11½
19	47	30	19	24	30	11	30
20	45	0	20	22	15	11	22½
21	42	15	21	19	30	11	22½
22	38	0	22	15	30	11	15
23	34	40	23	12	0	11	20
24	29	35	24	7	0	11	17
25	22	20	25	Fro N. to w. o. 8.		11	14

The

The eleuation of the Sunne vpon the Meridian. 25. d. 58'. the declination 12. d. 30'. which I adde to the eleuation, because the Sunne hath south declination, and thereof amounteth 38. d. 28'. the eleuation of the equinoctiall, the which I substract from 90. d. the rest is 51. d. 32'. the eleuation of the Pole Artike.

Now are you to consider, that out of the greate Variation of a shadowe vppon any degrée of the Sunnes eleuation, is to be taken the lesser of the same degrees eluation, whether it bee in the forenoone or afternoone (except the same variations bee both one way from the North of the Néedle, which then are to be added) the halfe of the remainer, is the variation of the Needle, or Compasse, from the Pole or true Meridian.

In the former obseruations, I do finde the greatest variation in the forenoone, for at 17. d. eleuation, the variatiõ is 52. d. 35'. from North to West: And at the same eleuation in the forenoone, I finde the variation to bee but 30. d. 0'. from North to East. I take the lesser out of the greater, and finde remaining 22. d. 35'. the halfe thereof is 11. d. 17'. ½. So muste I say to the Pole Artike, and true Meridian line that passeth to the pole, by our Zenith at London, to the Westwards of the North that the Néedle sheweth. And therefore the Néedle or Compas varieth from the true north, 11. d. 17'. ½. to the eastwardes.

Also at 25. d. eleuation in the forenoone, the variation is 22. d. 20'. from North to West, at the same eleuation in the afternoone, the variation is. 0. d. 8'. from North to West. Now because the variations are both one waye, (that is to the Westwards) I adde them together (and so ought you to doe, as often as you finde the variations so to agrée) & I finde that they amount to 22. d. 28'. the halfe thereof is 11. d. 14'. which is the variation.

The variations of the Néedle or compas by the former obseruations, are set out towardes the right hande against euery degrées eleuation, and conferring them altogether,

I doe finde the true variation of the Needle or Compas at Limehouse to be about 11.d ½ or 11.d ¾ which is a paint of the Compasse iust or little more, so that in a Compas whose wiers are set directly vnder the flowre de Luce, the North, and by West, and South and by East pointes doe shew the true Meridian.

The elevation of the Pole, and place of the Sunne, given, how vpon the Globe, to find the variation of the Needle by any one obseruation, either in forenoone or afternoone.

The fourth Chapter.

IN the former declaration, the onely ways to trie the variation, is by comparing of the seuerall correspondent obseruations of the Sunnes elevation in the forenoone, with those of the afternoone, so that if the Sunne should be obscured, or by any other occasion like obseruation cannot be made in the afternoon, then the former rule giueth not the desired purpose. Therfore I thought good to shew, howe by anie one obseruation in the fore or afternoone, the elevation of the Pole & place, of the Sunne giuen, you may knowe the true Meridian and the variation of the needle from the same in any place which thing may be done and aptly demonstrated vpon ỹ Globe, but most exactly calculated by the Table of signes.

To finde out the variation vpon the Globe, you must first set your Globe to stande duely according to the elevation of the Pole at the place proposed. Then seeke in the Ephemerides, for the true place of the Sunne that day, and note it with some small prick in the Ecliptick of the globe And placing the Quadrant of altitude or moueable verticall, at the verticall point or Zenith, take the elevation

of

of the sunne obserued by the Astrolobe or other Instrument at the time proposed, and note it iustlye vppon the same Quadrant of altitude. Then turne your Globe and Quadrant towards that parte of the Horizon that the sun was in at the time of the obseruation, tyll the pricke you made for the place of the sunne in the Ecliptick, concurre and agree iustly with the elouation marked in the sayde Quadrant of altitude: so shall you see the Quadrant shewe you vppon the Horizon, the Azimuth and distance of the sunne from the true Meridian of that place, which you shall compare with the variation obserued vppon the Instrument at that instante of the Sunnes elouation. And if they agree and concurre iust, then shall you be in the true and common Meridian, which sheweth the Pole of the world, and Pole of the Magnes or Loadstone. But if they differ, you shal subtract the lesser from the greater, the remainer sheweth the Variation. And if the variation vpon the Instrument be greater then the true distance of the Azimuth from the Meridian found vpon the globe, the same surplus must be accounted for variation: vpon the contrarie side of the Meridian: if it be lesse, it is to be accounted on the same side of the Meridian that the variation is taken, whether it be in the forenoone or afternoone. This præcept needeth no further demonstration, then the instrument it selfe, this Globe I meane.

But for example of the worke, I take the firste obseruation, in the former Chapter specified, made at Limehouse, the sixteenth of October. 1580. in the forenoone, which is 17.d. elouation & variation 52.d.35′. from North to West.

First I set my Globe at 51.d.32′. for the elouation of the Pole. Secondly, I take the place of the Sun 2.d.55′.m. and note it vpon the Ecliptick. Thirdly, I note vpon the Quadrant of altitude, the elouation of the sunne 17.d. This done, I moue the quadrant of altitude towards the East of the Horizon, and turne the Globe till the pricke in

the Ecliptick for the place of the Sunne, do agree iuſtly, with the eleuation noted vpon the quadrant of altitude, & find the true azimuth shewed by the same quadrant vppon the Horizon to bee neereſt, about 41. from the Meridian: and conferring the same with the variation found vppon the Inſtrument 52 d. 35'. I finde the difference 11 d. 15' and becauſe the obſeruation is noted to be in the forenoone from the North to the Weſt, or South to the Eaſt, and the variation vpon the Inſtrument greater then the azimuth found on the Globe, I account the same from the North to the Eaſt, or from the south to the Weſt. So I conclude the variation at Limehouſe to be about 11. $\frac{1}{4}$ from North to Eaſt, or south to Weſt.

How to finde the Variation by Arithmeticall calculation vppon any one obſeruation in the forenoone or afternoone, the latitude of the place, and declination of the Sunne being giuen.

The fift Chapter.

THe ſumme of the woorke is to finde the arke of the Horizon betweene the meridian and the azimuth of the ſunne at the time of the obſeruation, which being compared with the variation found in the Inſtrument, the difference is the Variation of the Needle. For attaining of the same arke. Firſt it is neceſſarie to haue the arke of the Equinoctiall betweene the ſunne at the time of the obſeruation, and the meridian, which arke is thus found.

Multiplie the ſigne of the Sunnes Meridian altitude for the day propoſed by the whole ſigne, the product deuide by the ſigne of the eleuation of the Equinoctiall (or the complement of the latitude) the quotient is the hearſed ſigne or ſhaft of the Semidiurnall arke, which you ſhall

note

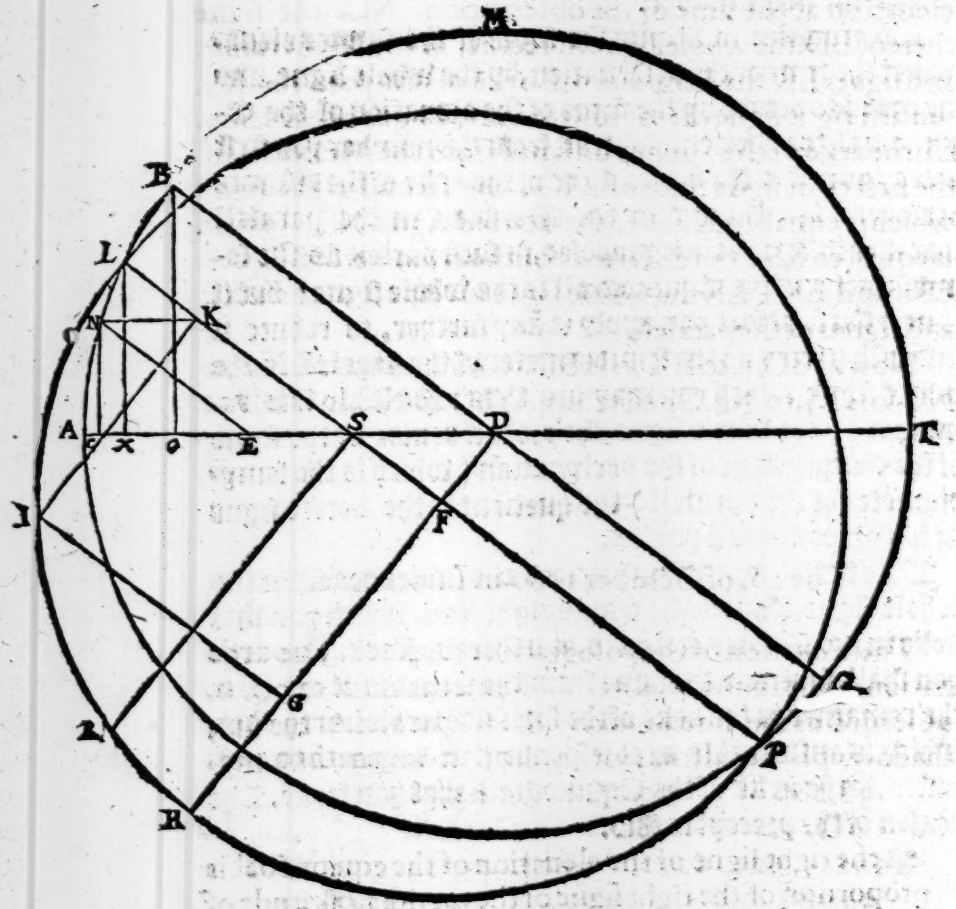
note for the first number.

Then againe multiplie the signe of the sunnes eleuation at the time of the obseruation, by the whole signe, and the product deuide by the signe of the eleuation of the Equinoctial, the quotient subtract from the number you first noted, the rest is the verſed signe of the arke of the distance betweene the sunne and the Meridian in the paralell that it is in for the time proposed, in such partes as the semidiameter of the Equinoctiall is the whole signe: but it is necessarie before you apply it any further, to reduce it into such partes as the semidiameter of the paralell is the whole signe, which you may doe thus: Multiply this remainer by the whole signe, the product deuide by the signe of the complyment of the declynation (which is the semydiameter of the paralell) the quotient is the verſed signe in his proportionall partes.

This verſed signe thus reduced and subtracted from the whole signe, leaueth the second right sign, which you shal seeke in the Tables of signes, and thereby finding his arke you shall subtracte the same from the Quadrant or 90. d. the remainer is the arke of the foresaid paralell of the sun, which is answerable or coresponden in degrées and mynutes, to the arke of the Equinoctiall that you seeke. The reason of the precept is this.

As the right signe of the eleuation of the equinoctial, is in proportion of the right signe of the meridian altitude of the sunne or any star: so is the whole signe, to the verſed signe of the semidiurnall arke. And againe, as the right sign of the meridian altitude, is to the right signe of the eleuation of the sun or star at the time of the obseruatiō, so is the verſed signe of the semidiurnal arke of the same, to the excesse or difference between the same verſed signe and the verſed signe of the distance from the meridian.

For the better vnderstanding of the premises, I haue set downe this figure following, and wish the Reader to consider of the same with the 4. Pro. of the 6. of Euclide.



LEt AMT. bee the meridian circle. BDQ the common section of the meridian, and Equinoctiall theyr plaines, which is also the diameter of both circles. ADT. the plaine of the Horizon. LHP. the paralell of the Sun, which is described vpon the center F. at the distance FL. which is the sign of the complement of the declination AB. the arke of the eleuation of the Equinoctiall BO. the first right signe thereof AL, the arke of the meridian altytude LX. the signe thereof. AN. the arke of the Sunnes eluati-

eleuation at the time of the obseruation. NC. the signe thereof BD. the whole signe in respect of the former arkes and signes LR the Semidiurnall arke of the paralell. RS. the first right signe therof SL, the versed signe of the same. LI, the arke of the Sunnes distance from the Meridian IK the first right signe thereof. IG. the second right signe which is equall to KF. KL. the vearsed signe NE. whych is equall to KS. the difference of the twoo versed signes. LS. and LK, LF. the whole signe in respect of the arkes and signes of the paralell.

Now as BO. is to LX. so is BD. to LS. And as LX. to NC. so is LS. to NE. Or else thus, As BO. to NC. so is BD to NE.

Example.

The 16. of October 1580. in Limehouse.

The eleuation of the pole Articke 51.d.32′. The declination of the sunne 12.d.30′. The eleuation of the sunne obserued in the forenoone. 17.d.0′. The variation of the shadow vpō the instrument 52.d.35′. from north to west.

′	38.28′.	90.0′.	25.58′.	
	BO.	BD.	LX.	LS
If	62205.	giue 100000.	then 43784.	giueth 70386.
	38.28′.	90.0′.	17.0′.	
	BO.	BD.	NC.	NE.

Againe, if 62205. giue 100000. 2937. shall giue 47001.

Now out of LS. — 70386.
take NE — 47001.
Rest LK. — 23385.

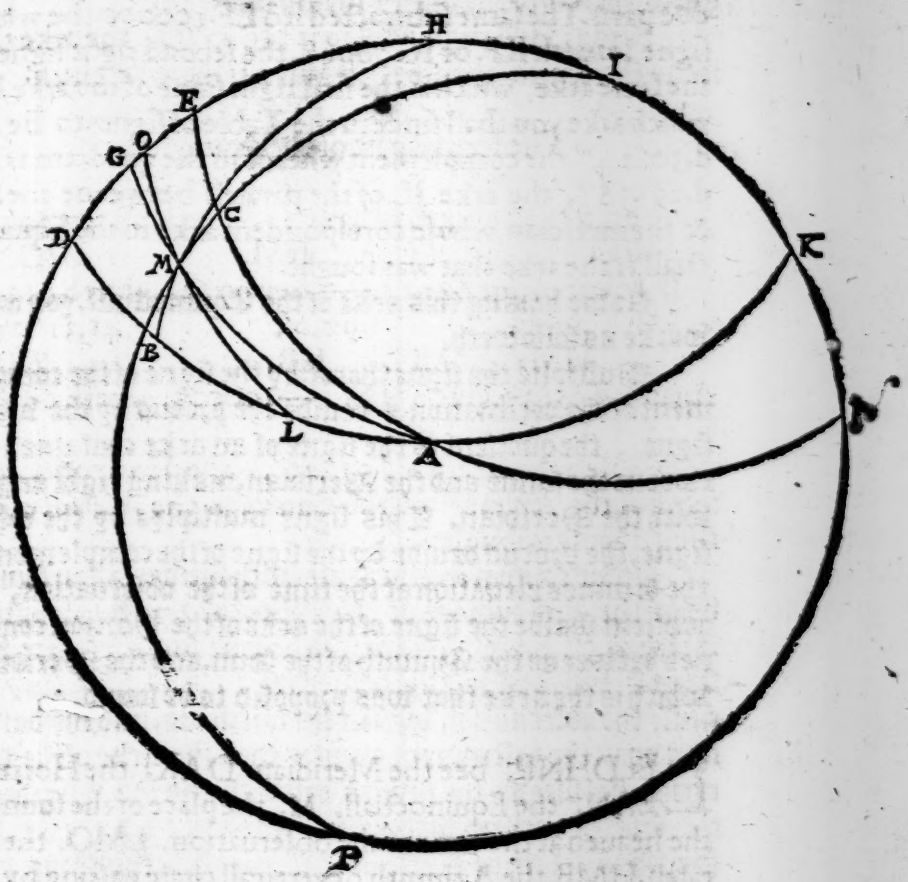
Then if LF. 97629. the signe of 77.d.30′. the complement of the declination, giue LF. 100000 then IK. 13385 giueth IK. 23952. the vearsed signe of the Arke IL. is his

due parts. The same subtracted frō LF. 100000. the whole signe, leaueth KF. or IG. 76048. the second right signe of the same arke, which is the first right signe of the arke IH. which arke you shall finde in the Table of signes to be 49. d. 30'. 24''. the complement wherof to the quadrant is 40. d. 29'. 36''. the arke IL. of the paralell betweene the sun & the meridian, whose coresponden arke in the Equinoctiall, is the arke that was sought.

Nowe hauing this arke of the Equinoctiall, you must worke as followeth.

Multiplie the signe therof, by the signe of the complement of the declination, & deuide the product by the whole signe, the quotient is the signe of an arke contained betweene the sunne and the Meridian, making right angles with the Meridian. This signe multiplye by the whole signe, the product deuide by the signe of the complement of the Sunnes eleuation at the time of the obseruation, the quotient shalbe the signe of the arke of the Horizon contained betweene the Azimuth of the Sun, and the Meridian, which is the arke that was proposed to be found.

LEt DHNP. bee the Meridian. DAK. the Horizon. EAN. the Equinoctiall. M. the place of the sunne in the heauen at the time of the obseruation. LMO. the paralell. HMB. the Azimuth or verticall circle passing by the Sunne. A*M*G, a great circle imagined to passe by the sunne, and to crosse the meridian at right angles. I*M*P, a great circle passing by the poles of the world, and place of the sunne at the time of the obseruation, commonly called the circle of houres, or circle of declination. CM. the south declination of the sunne. MP. the complement therof to the quadrant. *M*G. the arke betweene the sunne and the *M*eridian of the former imagined circle. A*M*G*M*O. the Arke of the sunnes paralell. EC. the corresponden arke of the Equinoctiall, which are giuen in the former work. MB. the Eleuation of the sunne at the time of the obseruation.



tion. *M*H. the complement thereof. BD. the Arke of the Horizon intercepted betweene the Azimuth and the *M*eridian, whiche is the thing required to bee found.

In this figure the Reader is to consider the manner of the spherical triangles, and to compare the signes of their sides, according to the doctrine of Copernicus, in the 14. Chapter of his first booke, & of Regiomontanus, his 25 and 27. Propositions of his 4. booke of triangles.

As PC. is to CE. so is PM. to MG. but three of them are

giuen, therefore the fourth shalbe knowen.

And as HM. is to MG so is HB to *BD* the arke that is sought, which by three first giuen is likewise giuen.

The second part of the example.

90.0°.	40.29′.36″.		77.30′.
PC.	EC.	PM.	*MG.*

If 100000. giue 64935. —— then 97629. giueth 63395.

37.0′.	90.0′.	41.31′.22″.
HM.	MG. HB.	*BD*

Againe, if 95630. giue 63395. —— 100000. giueth 66291.

Whose arke *BD*, 41.d 31′.22′. is the Horizontall distance of the Azimuth of the Sun from the *M*eridian, the thing that was sought.

Nowe comparing the same with the variation founde vpon the Instrument at the instant of 17. d. eleuation which is 52.d.35′. I finde it to be lesse, and therefore substract it, and so haue I the difference 11.d.3′.38″. And because the obseruation was in the forenoone, and the variation vpon the instrument greater then the arke of the Horizon, betweene the sunnes azimuth and the Meridian, therfore I conclude that the variation is 11.d.3′38″. frō South to West, or North to East, which is the thing promised to be shewed.

But comparing the same arke of the Horizon 41.d.31′ 22″. with the variation found at the correspondent eleuation in the afternoone, which is 30′. I substracte the lesser from the greater, & find the excesse 11.d.31′22′. which should be the variation. And because the variation found vppon the Instrument is lesse then the arke of the azimuth vppon the Horizon, I account the variation on the same side of the Meridian, which is from South to West, or North to East.

This varietie betwæne the obseruation made in the fore-

forenoone, and that in the afternoone, proceedeth either of the imperfection of the instrument, or negligence of the obseruer. For in the rule there can be no error, being grounded vppon Geometricall demonstration, then which, nothing can be more certaine.

The former precepts and examples do serue when the sunne dooth decline from the Equinoctiall either Northwards or southwards. But if the sunne be in the Equinoctiall, then the manner of the woorking is more easie and briefe. For if you multiply the signe of the Sunnes eleuation at the time of obseruation, by the whole signe, and deuide the product by the signe of the eleuation of the Equinoctiall, which is the meridian altitude, the quotient giueth the second right signe of the distance of the sun from the meridian, which is the first right signe of the complement of the same arke: and entring the Table of signes with it you shall finde his arke, which if you subtract from the Quadrant or 90. d. leaueth the arke of the distance of the sunne from the meridian. And hauing the same worke thus. If the signe of the complement of the eleuation of the sunne at the time of the obseruation, giue the signe of the foresaid arke of distance, what shall the whole signe giue? Multiplie and deuide, the quotient shalbe the signe of the arke of the Horizon contained betweene the Azimuth of the Sunne and the Meridian. Which arke being compared with the Variation of the Instrument in manner as before is shewed, giueth the variation required.

But the sunne being in the Equinoctiall, if the place wher the obseruation is made, be likewise vnder the same circle, then is the variation most easily obserued, for that the Equinoctiall is the azimuth of East and West, therefore turning your Instrument onelie to receiue the shadowe of the Sunne, and looking then to the North point of the Needle, if you finde the same to aunswere to the Quadrant or 90. d. you shall bee in the Meridian of the Magnes, which passeth by the Poles of the world, but if it

doe

giuen, therefore the fourth shalbe knowen.

And as HM. is to MG so is HB to *BD* the arke that is sought, which by three first giuen is likewise giuen.

The second part of the example.

90.0°.	40.29′.36″.		77.30′.
PC.	EC.	PM.	*MG.*
If 100000. giue	64935.	—then 97629.	giueth 63395.
37.0′.	90.0′.		41.31′.22″.
HM.	MG.	HB.	*BD*
Againe, if 95630. giue	63395.	—100000.	giueth 66291.

Whose arke *BD*, 41.d.31′.22′. is the Horizontall distance of the Azimuth of the Sun from the *M*eridian, the thing that was sought.

Nowe comparing the same with the variation founde vpon the Instrument at the instant of 17. d. eleuation which is 52.d.35′. I finde it to be lesse, and therefore substract it, and so haue I the difference 11.d.3′.38″. And because the obseruation was in the forenoone, and the variation vpon the instrument greater then the arke of the Horizon, betweene the sunnes azimuth and the Meridian, therfore I conclude that the variation is 11.d.3′38″. frō South to West, or North to East, which is the thing promised to be shewed.

But comparing the same arke of the Horizon 41.d.31′ 22″. with the variation found at the correspondent eleuation in the afternoone, which is 30 0′. I substracte the lesser from the greater, & find the excesse 11.d.31′22′. which should be the variation. And because the variation found vppon the Instrument is lesse then the arke of the azimuth vppon the Horizon, I account the variation on the same side of the Meridian, which is from South to West, or North to East.

This varietie betwæne the obseruation made in the fore-

forenoone, and that in the afternoone, proceedeth either of the imperfection of the instrument, or negligence of the obseruer. For in the rule there can be no error, being grounded vppon Geometricall demonstration, then which, nothing can be more certaine.

The former precepts and examples do serue when the sunne dooth decline from the Equinoctiall either Northwards or southwards. But if the sunne be in the Equinoctiall, then the manner of the woorking is more easie and briefe. For if you multiply the signe of the Sunnes eleuation at the time of obseruation, by the whole signe, and deuide the produce by the signe of the eleuation of the Equinoctiall, which is the meridian altitude, the quotient giueth the second right signe of the distance of the sun from the meridian, which is the first right signe of the complement of the same arke: and entring the Table of signes with it you shall finde his arke, which if you subtract from the Quadrant or 90. d. leaueth the arke of the distance of the sunne from the meridian. And hauing the same worke thus. If the signe of the complement of the eleuation of the sunne at the time of the obseruation, giue the signe of the foresaid arke of distance, what shall the whole signe giue? Multiplie and deuide, the quotient shalbe the signe of the arke of the Horizon contained betweene the Azimuth of the Sunne and the Meridian. Which arke being compared with the Variation of the Instrument in manner as before is shewed, giueth the variation required.

But the sunne being in the Equinoctiall, if the place wher the obseruation is made, be likewise vnder the same circle, then is the variation most easily obserued, for that the Equinoctiall is the azimuth of East and West, therefore turning your Instrument onelie to receiue the shadowe of the Sunne, and looking then to the North point of the Needle, if you finde the same to aunswere to the Quadrant or 90. d. you shall bee in the Meridian of the Magnes, which passeth by the Poles of the world, but if it

does

doe differ from 90. d. the same difference is the variation of the needle.

But admitting the obseruer to be vnder the Equinoctiall, and the sunne to haue Declination, then the proportion of the signe of the complement of the elevation at the time of the obseruation, vnto the signe of the declination shalbe such, as the whole signe, is to the signe of the ark of the Horizon included betweene the Azimuth of East and West, which is the Equinoctiall it selfe, and the azimuth of the sun for the time of the obseruation, the complement whereof giueth the true Meridian, which complement you may compare with the variation shewed vpon the Instrument, the difference is the variation.

Diuers other cases might be proposed, and rules gyuen for them, which for breuity I omit.

But one thing I thought good to admonish you by the way, that whereas I haue shewed in the first parte of this proposition, the manner to finde the twoo vearsed signes, the one of the Semidiurnall arke, the other of the arke of the distaunce of the sunne from the Meridian. If the first the semidiurnall ark being found and reduced into houres and minutes of time, is shewed the iust halfe quantitie of the day. And by the arke of the other likewise reduced, the houre of the day, or the time contained betweene the noone steed and the instant of the obseruatiō: as in the same example.

The versed signe of the Semidiurnall arke. LS is gyuen 70386. in such parts as the semidiameter of the equinoctial *BD* is 100000. therfore I reduce the same into such partes as the semidiameter of the paralell LF. is 100000. and finde it to bee 72095. whyche subtracted from the whole signe *LF* 100000. there resteth *SF* 27905. whych is the seconde right signe of the semidiurnall arke LR. and the right signe of RH 16. d. 12′. which is the complement of the Semidiurnall arke *LR* wherefore subtracting it from the Quadraunt *LH* 90. d. resteth 73. d. 48′.

the

the Semidiurnall arke *LR* the same reduced into partes of time alowing 15.d. for a houre 15′. for a minute, & 15″ for a seconde of time, and for euerie degree 4. minutes of time, for euerie minute 4″. and for euerie second 4‴. &c. I finde the time of that arke from the time ascendent, to the Meridian, which is halfe the day, to be 4. houres 55′ 12″. and consequently the whole day being the 16 of October aboue written, to be 9. houres 50′. 24″. long.

This example may serue for a generall precedent, whiles the equinoctiall is betweene the sunne and the eleuated Pole, but if the sunne bee betweene the eleuated Pole, and the Equinoctiall, then will the versed signe fall out to bee greater then the whole signe, and the semidiurnall arke to exceede a Quadrant. Wherefore hauing reduced the same into his proportionall parts, as before is shewed: subtract from it the whole signe, the surplus is the signe of the excesse of the Semidiurnall arke aboue a Quadraunt, which being added to the Quadrant, giueth the semidiurnall arke.

By the other versed signe of the distance of the sunne from the Meridian, which is LK. 23952. in such partes as the whole signe or Semidiameter *LF* is 100000. subtracted from the whole signe, is giuen KF. 76048. the seconde right signe of the same arke of distance, and the first right signe of 49.d. 30′. 24″. which is the complement of the arke of the Sunnes distance from the Meridian: therefore subtracting the same from 90.d resteth 40.d. 29′. 36″. the arke of the distaunce betweene the sunne and the Meridian, which beeing reduced into partes of time as before, giueth 2. houres 41′. 58″. and the same (because it is in the forenoone) deducted from 12. houres the noone tyed, resteth 9. houres 18′. 2″. the iust instant of the time of the daie.

But if this versed signe be found to be greater then the whole signe (as it may when the sunne is betweene the Equinoctiall and the eleuated Pole, and before the houre

or five in the morning, and after the houre of five in the euening) then dooth the arke of distance consequentlye exceede a Quadrant, the signe of this excesse is the surplus of the versed signs aboue the whole signe. Whose arke added to the Quadrant, giueth the arke of the sunnes distaunce from the meridian, and reducing the same into partes of time, is giuen the instant of time of the obseruation.

As by this meanes (the eleuation of the sunne beeing precisely obserued and latitude knowne) the instaunt of tyme of the daye is gyuen more exactlie, then by anie Clocke, Diall, or other Instrument. Soif there might be had a portable Clock that would continue true the space of 40. or 50. houres together (if longer tyme the better) then might the difference of longitude of any twoo places of knowen Latitudes, which conuenientlye may be bee trauailed within that tyme, bee also most exactly giuen. And in this sorte trauailing and obseruing from place to place, might the Longitudes of any Countrie bee perfectlye described.

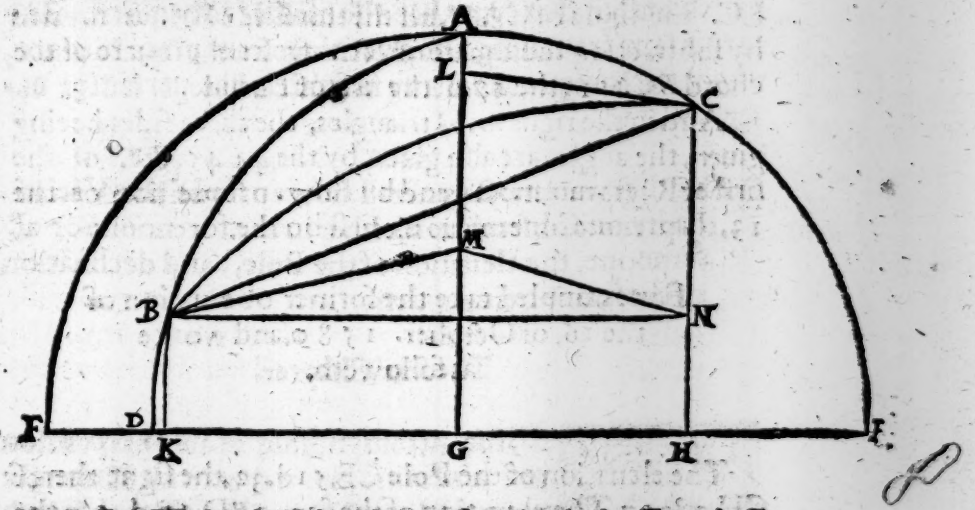
Another waie most generall, how to finde the Variation by one obseruation, either in the forenoone or afternoone, the eleuation of the Pole, and declination of the sunne being giuen.

The sixt Chapter.

FOr the accomplishing of this proposition you are to imagine a sphericall Triangle vpon the superficies of the Globe, whose sides must be. First, the portion or arke of the meridian betweene your Zenith and the Pole, which is the complement of the latitude. The second the arke of the verticle circle contained betweene your Zenith & the sun, which is the complement of the suns eleuation at the time of the obseruation.

The

The third side is an arke of the circle of declination comprehended betweene the sunne and the eleuated Pole, this arke is found by adding, or subtracting the declination of the sunne, to or from, the Quadrant or 90. d. which must be done with this consideration, that if you be on the same side of the Equinoctiall that the sunne is, you are to subtract the declination from the Quadrant. If on the other side, to ad it to the same, so haue you the three sides of the sphericall triangle giuen. Then the substance of the worke consisteth in finding the quantitie of the angle of the same triangle at the Zenith, for the complement thereof to the Semicircle or two right Angles, is the Horizontall distance of the Sunnes Azimuth, from the Meridian, which beeing compared with the variation of the Sunns shadowe vpon the Instrument, giueth the thing required.



LEt FACE. be the Meridian, wherein A. the Zenith, C the Pole. AD. the verticall circle of Azimuth of the Sunne passing by B. the place of the Sunne at the tyme of the obseruation. BD. the eleuation of the Sunne. BA. The complement of the eleuation AC. the complemẽt of the latitude. BC. the arke of the circle of declination, or

the

the chord of the same arke. FGE. the plaine of the Horizon.

Now from the three angles of the triangle ABC. let fall 3. perpendicular lines to the plaine of the Horizon. AG CH. and BK. and by the 6. of the 11. of Euclide, these three lines shalbe paralels.

Then let fall a perpendicular line from C. vpon AG. in the point L. from *B*. another perpendicular vpon the same line AG. at the point *M*. And from the same point *M*. erect a perpendicular line to N. which shalbe paralell and equall to LC. Then ioine *B*. and N. together. So haue you a right lined triangle. *BM*N. whose angle at *M*. is equall to the angle A. of the spherical triangle *ABC*. By the 4. definitió of the 11. Euclide, for the like reason is of obtuse angles as of acute or sharpe. And the sides thereof *BM*. and *M*N. are giuen *BM*. the signe of *B*A. and *M*N. equal to LC. the signe of CA. And the third side BN. is founde by subtracting the square of NC. from the square of the chord *B*C. as in the 47. of the first of Euclide.

And in the right lined triangles, the three sides beeing giuen, the angles are also giuen, by the 44. 45. &c.° of the first of Regiomontanus, and by the 7. proposition of the 13. chapter of Copernicus his first booke.

For example I take the former oberuation of the 16. of October. 1580. and worke as followeth.

The eleuation of the Pole CE. 51 d. 32. the signe therof CH. 78297. The eleuation of the sunne *B*D. 17. d. 0′. the signe thereof *BK*. 29237. The Arke *BC*. 102. d. 30′. the chord thereof *BC*. 155970. The complement of the eleuation of the sunne *BA*. 73. d. 0′. the signe thereof *BM*. 95630. the complement of the Latitude AC. 38. d. 28′. the signe thereof LC. 62205. equall to *M*N.

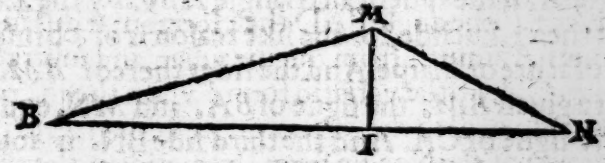
Now

Nowe out of CH. 78297. ſubtract NH. equall to BK. 29237. Reſt NC. 59060.

Then out of the chord BC. ſquared. —— 4432851257 6.
Take the ſquare of NC —— 3486883600.

Reſt the ſquare of BN —— 2192162897 6.
The root therof is 148059. the ſide BN.

So are the three ſides of the triangle giuen. { BN. 148059 / MN. 62205. / BM. 95630.



Now I finde the angle MI. ſubtract from the ſquare of *BM*. the bigger ſide, which is 9145096900. the ſquare of *MN*, the leſſer ſide, which is 3869462025. Reſt 5275634875, which deuided by the baſe *BN*. 148059. giueth 35631, the halfe thereof 56214 is IN. the leſſer caſe or ſhorter part of the baſe deuided by the perpendicular line MI, falling vpon the ſame from the obtuſe angle M. which ſubtracted from the whole baſe *BN* 148059 leaueth I*B* 91845, the greater caſe or longer part thereof.

Now it is manifeſt that theſe two caſes or parts of the baſe *BI* and IN are the ſignes of the twoo ſharpe angles IM*B*. and N*M*I made of the obtuſe angle *M* by the perpendicular falling from the ſame angle to the baſe, and the arkes of them ioined together, are the quantity of the obtuſe angle N*MB*.

Therefore to reduce them to the numbers of the ſignes firſt for the greater caſe *BI* making *BM* the whole ſigne, ſay.

BM

BM. BM. BI. BI.
If 95630. giue 100000. then shall 91845. giue 96042.

The arke therof is 73.d.49.'.38.''. Againe for the lesser case, making *M*N. the whole signe, say.

*M*N. *M*N. IN. IN.
If 62205. giue 100000. —— then 56214. giueth 90376.

Whose arke is 64.d.38.'.45.''. And adding these two arks together, they giue 138.d.28.'.23.''. the ark or quantity of the obtuse angle NMB equall to the spherical angle BAC and deducting it from the Semicirele 180.d. there resteth 41.d.31.'.37.''. the angle FAD the Horizontal distance of the Sunnes Azimuth from the meridian, and subtracting that from 52.d.35. the variatiō found vpon the instrumet from northto west in the forenoone, resteth 11.d.3.'.23.'' the variation of the Needle from the meridian, the thinge that was proposed to be found. And comparing the same with the afternoons obseruation, you shal find it 11.d.31.'37.''. the cause of this difference I haue declared in the former chapter.

If the Reader bee delighted with varietie of demonstration of this matter, let him peruse the 34 Proposition of the 4. of Regiomontanus, and the 13. Proposition of the 14. Chapter of the first booke of Copernicus.

But whereas you see this calculation to differ from the former in some odde secondes, the reason thereof is not as it might be taken the different nature of the rules, but in working thereof, omitting the fractions in the deuisions, and neglecting the proportionall partes of the signes and arkes.

In these examples I haue vsed the abridged Table of 100000. the whole signe, which though it giue some ease in the working, yet it is not so exact as that of 10000000. of Erasmus Reinholdus. Vnto the which, with his Canon fœcundus answerable to the same, if the third canon of the

Hypo-

Hypothenusaes were annexed, wee should haue an entire Table for the doctrine of triangles, that might worthilye be called the table of tables. Which thing though Georgicus Ioachimus Rheticus, haue wel begunne and framed it orderly from ten minutes to ten: yet is it left very rawly, for such as desire the exact truth of things. I haue therefore for mine own ease and vse, calculated the complement of this Table, and almost ended, if for the whole quadrant from minute to minute: which if in the meane time before I haue finished, I shall not finde it extant by anie other, I will publish it for the commoditie of al such as shall haue occasion to vse the same for Nauigation and Cosmographie.

To find the eleuation of the pole, scituation of the Meridian, and variation of the Needle, at any place by the sun, vpon two obseruations, either in forenoone or afternoone.

The seuenth Chapter.

Whereas in the three laste Chapters, the groundes of the calculations consist in the Eleuation of the Pole to bee giuen, which thing to know is no lesse difficult, then the chiefe matter that is by them required: for the common preceptes, which as yet haue chiefly been giuen for the finding therof, depend only vpon the obseruation of the Meridian altitude of the Sunne or starres, or else vpon certaine false and grosse rules of the guardes and pole starre. Therefore I haue thought good that as I haue shewed the way to knowe the variation, vppon any one obseruation, either in forenoone or afternoone, the latitude of the place presupposed: So likewise vpon two obseruations by the same, either in forenoone or afternoone, to set downe the way and manner howe to

finde the elenation of the Pole, scituation of the Meridian, and the variation of the Needle in anie place by the Globe.

But this you must alwaies regard, that your two obseruations may haue conuenient distance of time betweene them, the greater the better: So as the higher elenation be not taken neere the Meridian, the lower elenation, the neerer it is taken to the Azimuth of East or West, or to the Horizon the better, with which elenations you are to note the difference of the Sunnes Azimuths or Variations founde by the shadowe vppon the instrument exactlye, for without that the elenations onelie are in vaine.

First it is requisite that your Globe be so fitted, that the meridian circle and the Horizon do crosse each other at right angles, and deuide themselues equallie into Semicircles. And also that the Quadrant of altitude (or moueable verticall) be placed dulie vpon the Meridian circle at the Zenith, so as beeing turned circularlie, it may touch the Horizon equallie in euerie part. These things beeing dulie considered, there needeth not anie further regard to be had for placing of the Globe, onelie this you may respect in setting the Pole at aduentures aboue the Horizon, betweene it and the Zenith, that the meridian circle may cut the Horizon in iust degrees, so may your Quadrant of altitude be placed in your Zenith iustly vpon 90 degrees also.

Then must you fasten your Globe to the Horizon, so as it may remaine immoueable, but in fastning the same you must regarde that you force it not from one side of the Horizon to another, but that it rest equidistãt in the same, and hauing your Globe thus disposed, it is ready for you to applie your obseruations vppon, which you shall thus doe.

First, take your highest elenation, and note it vpon your Quadrant of altitude, and place the ende of the said Quadrant vpon the Horizon at 10. 15. or 20. &c. from the Meri-

dian

almicantels (but the nearer you set the same to the meridian, the more conueniently, without impeachment will your triall bee made.) Then giue a pricke vppon the Globe in the azimuth, that the Quadrant sheweth at the degree of the elevation noted vppon the Quadrant, then againe note the lesser elevation vpon the Quadrant of altitude, and remooue the same vpon the Horizon, (from that place wher it was first fixed, towards the azimuth of East or West (which shalbe neerest the same) so many degrees as you finde the differences of azimuths betweene the twoo elevations by the shadowe of the sunne, vppon the instrument of Variation, and staying your quadrant of altitude vpon that point of the Horizon: note also your lesser elevation in the same azimuth vppon your Globe. Thus doon, you must haue a pair of Calliper Compasses, such as may conueniently reach to 113. d. ½ of the Equinoctiall of your Globe, (which is a Quadrant, and the greatest declination of the Sun) then you must cõsider which of the Poles of the world is elevated aboue your Horizon, and whether your declination be towards, or from that Pole, that is to say, whether the Sun be betweene the elevated Pole, and the Equinoctiall, or the Equinoctiall betweene the sunne & the Pole. If the sun be betweene the Pole and the Equinoctiall, then are you to detract the declination from 90. d. If the Equinoctiall be betweene the sun and the Pole, you must adde the declination to 90. d. And take the same remaining or collected number of degrees &c. with your compasses vpon the Equinoctiall. And set the one end of your compas at the pricke made vpon your Globe, for the highest obseruation, and with the other end discribe an arke or peece of a circle, vppon the same side of the meridian that your pricke is on, from the meridian to the Horizon. Then againe with your compas vnaltered, setting the one foot in the pricke for the lowest obseruation, describe an other peece of a like circle crossing the former: the point of the intersection, or crossing of these 2. circles, is the elevated pole, to the

which if you remoue the Quadrant of altitude, you shall find what the eleuation thereof is. And the point that the same Quadrant sheweth vpon the Horizon, is the intersection of the Meridian and the Horizon, the Horizontall distaunce betweene this intersection, and the azimuth of the lesser obseruation, subtracted from the Semicircle, or 180.d leaueth the Horizontall distaunce of the same azimuth from the true meridian. So haue you the eleuation of the Pole, and scituation of the meridian.

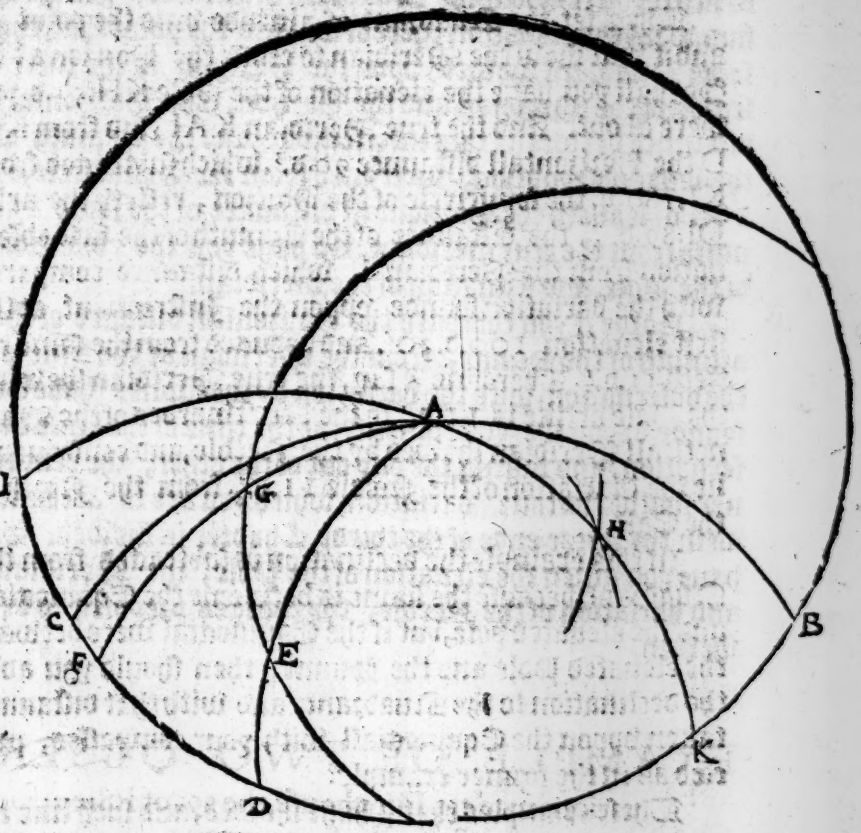
Nowe if you compare the Horizontall distance of the azimuth of the Sunne, from the Meridian at the time of the obseruation, with the variation by the sunnes shadowe founde vppon the Instrument, at the time of the same obseruation, and taking the one out of the other, the remainer shalbe the true variation, which you are to account, as in the latter ende of the thirde Chapter is shewed. So haue you giuen the eleuation of the Pole, the Meridian, and variation of the Needle, the thinges propoſed to bee shewed.

EXAMPLE OF TWO OBSERuations made at Limehouse, the 29. of Iulie 1581. in the forenoone.

The first eleuation 21.d.0′. Variation 100.d.30′. from North to West. The second eleuation 50.d.0′. Variation 48 d.0′. from North to West, Difference of the Azimuth 52.d.30′. The Declination 16.d.14′. Northerlie.

LEt IDB. be the Horizon of the Globe. CAB. the Meridian circle. FGA. the Azimuth of the greater eleuation shewed by the Quadrant of altitude vpon the Horizon at F. 10.d. from the meridian circle of the globe. C.FG the greater eleuation marked vppon the Globe at G. FD

the



the difference of the Azimuth vpon the Horizon. 52. d. 30'. E. the pricke of the lesser eleuation marked vpon the Globe in the Azimuth AED.

Then opening your Compasses to 73. d. 46'. of the Equinoctiall (which is the complement of the declination) and setting one end vpon G. the point of the greater eleuation, describe with the other ende, an arke or peece of a circle at H.

This doone, set one foot of the Compas vnaltered in E. the lesser eleuation, and with the other end describe a peece of a circle crossing the former arke at H. this intersecti-

on shall be the eleuated Pole.

Then set the Quadrant of altitude vnto the point H. and it will shewe the Meridian to crosse the Horizon at K. So shall you haue the eleuation of the Pole KH. 51.d.$\frac{1}{2}$. or there about. And the true Meridian KAI And from K to D the Horizontall distaunce 90.d.$\frac{1}{4}$. which subtracted from KI. 180.d. the semicircle of the Horizon, resteth the arke DI. 89.d.$\frac{1}{4}$. the distaunce of the Azimuth of the first obseruation from the Meridian I. which distaunce compared with the variation founde vppon the Instrument at the first eleuation 100.d.30′. and deducted from the same resteth 11.d.$\frac{1}{4}$. Therefore I say, the true Meridian shewing the Pole artike is 11.d.$\frac{1}{2}$ to the Westwardes of the Magneticall Meridian shewed by the Needle, and consequentlie the Variation of the Needle 11.d.$\frac{1}{2}$. from the North to the East.

In this example the declination is subtracted from the Quadrant, because the sunne is betweene the Equinoctiall and the eleuated pole, but if the Equinoctial were betwen the eleuated Pole and the Sunne, then should you adde the declination to the Quadrant, and with that distaunce taken vppon the Equinoctiall with your compasses, proceed as in the former example.

These examples that I haue shewed, and such like experimentes to bee doone vppon the Globe, are easie to bee conceiued, and the reasons verie manifest: but the truth of the matter consisteth in the exactnesse of the instrumentes, and the orderlie application and handling of them.

I might heere haue annexed the manner, how vppon two obseruations of the Sunnes eleuation in forenoone or afternoone, and difference of the Azimuthes, to calculate the Premises more exactlye by the Table of Signes and doctrine of spericall Triangles: but that it is a verye tedious waie, and my meaning is rather to giue the Reader a proofe of the pleasaunt vse of these calculations

(which

(which I thinke I haue sufficiently doone in the former Chapters) then to cloie him at the first with the hard and painfull practise of manie examples. Notwithstanding, for the satisfaction of some, I will briefly set downe the ground and summe of the worke, which is this.

The Complements of your two eleuations, are twoo sides of a sphericall triangle not rectangle. The angle by these two knowne sides contained at the Zenith, is giuen by the difference of the Azimuthes or Variations vppon the instrument. Wherefore by the 28. of the 4. of Regiomontanus the third side (which is the arke comprehended betweene the two eleuations) and the other angles maie be giuen.

Then haue you another like triangle, whose three sides are these: the first, one of the foresaid complemẽts of eleuation: the second, the arke of the circle of declination, betweene the Sun at the instant of the same eleuation, and the Eleuated Pole. The third side is an arke of the Meridian betweene the Zenith and the Pole: which is the complement of the eleuation of the Pole, or latitude of the place.

The two first sides are alwaies giuen. For finding the third side, it is necessarie to knowe the angle that the two giuen sides containe, which is the difference of two angles, whereof one is an angle of the first Triangle giuen, the other an angle contained betweene the arke of the circle of declination, and the third side of the first Triangle, which angle is diuersely found, and being founde and substracted from the other angle, or that from it, the difference is the Angle of this other Tryangle: And so haue you in the Sphericall Triangle two sides, and the angle by the same two sides contained giuen. And by the same 28. of the fourth of Regiomontanus the third side is founde, the complement whereof is the eleuation of the Pole.

And the eleuation of the Pole, and declination of the

Sun being giuen, the fourth Chapter sheweth by one obſeruation, to finde the variation of the Needle.

Of the Pole of the Magnes.

The eight Chapter.

DIuers learned men haue iudged, and ſet down as a truth (grounded vpon repoꝛte) that the meridian common to the Pole of the woꝛld, & the Pole of the Magnes (that is to ſay, where the Needle touched with the Magnes, ſheweth the Pole of ẏ woꝛld directly) paſſeth at the Ilands of the Acores, oꝛ neere there about, (but I find by great pꝛobabillity, that it ſhould be to the Weſtwards of thoſe Ilands.) From which meridian at the Acores, I account the beginning of Longitudes, and find our Meridian of London, to be from the ſame, 23. d. ½ our Latitude as beforꝛe ſaid. 51. d. 32′. and the variation of the Compas oꝛ Needle. 11 d. ¼ from the Noꝛth to ẏe eaſtwards. Now vpon theſe grounds I finde by calculation, the Pole of the Magnes, oꝛ the interſectiõ of the two Magnetical meridians, vpon the ſuperficies of the earth, to bee from the Pole artik 25. d. 44′. & in longitude 180. d. that is to ſay, 25. d. 44′. in the foꝛmer common meridian, on the other ſide of the Pole.

It may bee happilie that ſome of you will be deſirous to know the way how this Magnetical Pole is found out, that you may applie the ſame to like purpoſe heereafter. Therefoꝛe I thought good to ſet downe the manner of the foꝛmer calculation, by helpe of the declinations in the figurs following.

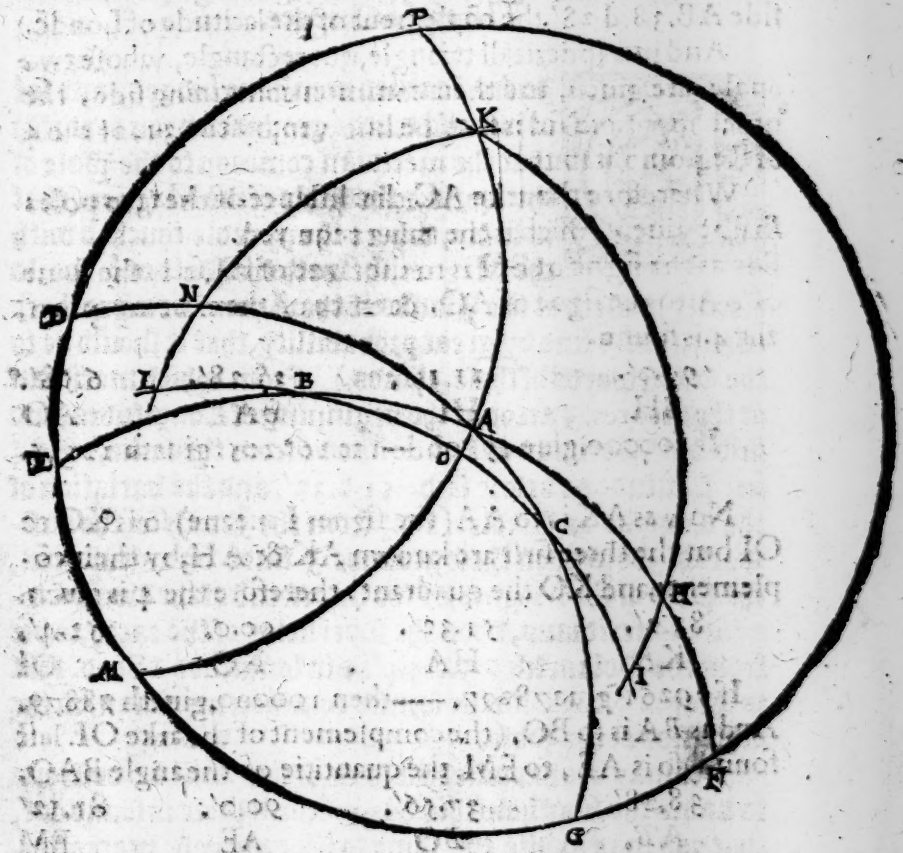
Example.

LEt A. be the Pole Artike. PEF. the Equinoctial. DAG. the common Meridian of the Pole Artik, and Pole of

the

the *Magnes* EAF the meridian for London,

LOI the *Magneticall* meridian of London, *B*, for the place of London. HI the quantitie of the angle of Variation at the ende of the quadrants BH and BI, C the inter-



fection of the two magnetical meridians CL and CN two Quadrants of the saide *Magneticall* circles, including the arke LN the quantity of the angle at C. *PAM* the Semicircle of a Meridian crossing the *Magneticall Meridian* of *London* in the point O. at right angles.

Make out the quadrants IHK and LNK so shall they crosse themselues with the quadrant OAK at the point *K*

Now

Now haue you ABC a ſpherical triangle, two angles whereof, and the common containing ſide of them, are giuen ABC. 11. d. ½. the angle of variation at London, BAC. 156. d. 30′. the complement of the angle DAE (the difference of the longitudes) to 2 right angles. And the ſide AB. 38. d. 28′. the cõplement of the latitude of Londõ.

And in a ſpherical triangle, not rectangle, whoſe two angles are giuen, and their common containing ſide, the other angle and ſides ſhall be knowen, by the 31. of the 4. of Regiomontanus.

Wherefore the arke AC. the diſtance of the two poles ſhalbe giuen, which is the thing required.

For as the ſigne of BH is to the ſigne of HI, ſo is the ſigne of BA. to the ſigne of AO. & three of them being giuen, the 4. is found.

90.0′.	11.15′.	38.28′.	6.58′.
BH	HI	BA	AO

If 100000. giue 19509. — then 62205. giueth 12135.

Now as AK is to AA (the ſignes I meane) ſo is KO to OI. but the three firſt are known AK & AH, by their cõplements, and KO the quadrant: therefore the 4 is giuen.

83.2′.	51.32′.	90.0.	52.4′.
KA	HA	KO	OI

If 99261, giue 78297. — then 100000, giueth 78879.

And as BA is to BO. (the complement of the arke OI. laſt found) ſo is AE, to EM. the quantitie of the angle BAO.

38.28′.	37.56′.	90.0′.	81.12′
AB.	BO	AE	EM

If 62205. giue 61474. — then 100000. giueth 98824

So hauing EM. 18. d. 12′. the quantitie of the angle BAO I ſubſtracte the ſame from EG. 156. d. 30′. the quantitie of the whole angle BAC. reſt MG. 75. d. 18′. the quantitie of the angle CAO, to the which is equall the oppoſite angle PAD. And as AP. is to PD. ſo is AK to KN.

90.0′.	75.18′.	83.2′.	73.46.
AP	PD	AK	KN

If 100000. giue 96726, —— then 99261, giueth 96011′.

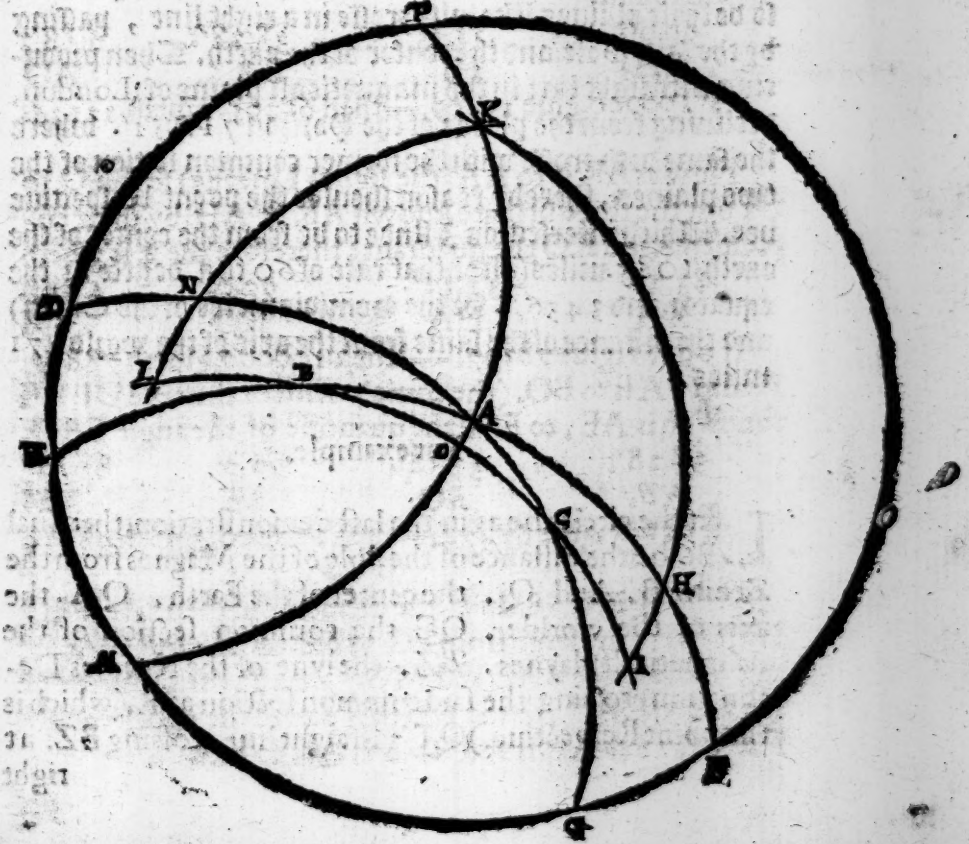
The complement of which arke KN is NL. 16.d.14′. the quantitie of the angle ABC. And as NL. is to NC, so is AO to AC. Wherefore I say.

16.14′.	65.8′.	25.44′.	
NL	NC	AO	AC.

If 27954. giue 100000. —— then 12135. giueth 43410.

Which is the distance of the pole of the Magnes from the Pole artike vpon the former Hipothesis, the thing that was sought.

Of



Of the point Respective.

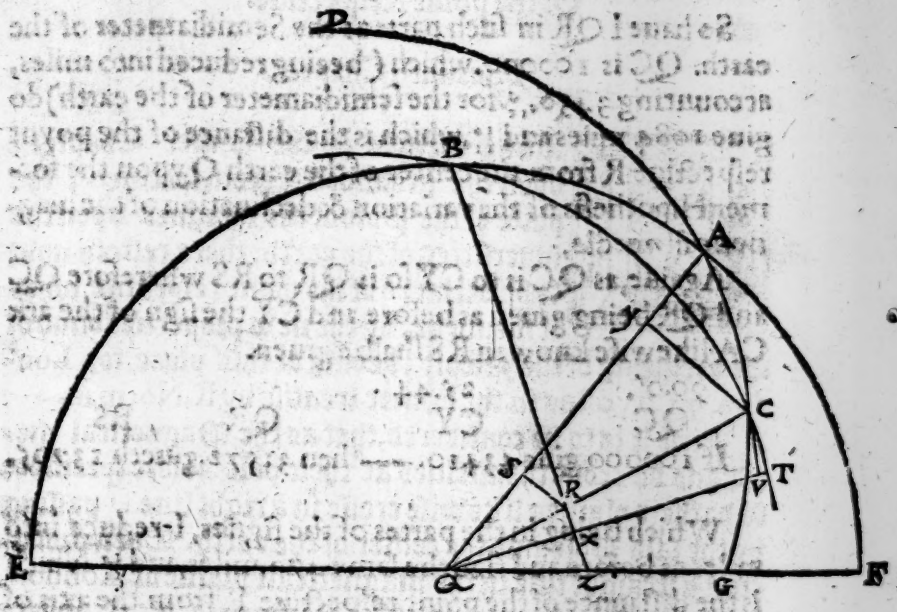
The ninth Chapter.

Having shewed in the former Chapter, vpon the groundes therein specified, the place of the Pole of the Magnes vpon the superficies of the earth: there resteth now to be declared of the point respective, wher it should be, by the new propertie found of the declining of the Needle, beeing at this place for London, 71.d.50'. as in the former treatise by R. Norman.

First it is to be considered, that as the Magnetical meridians do crosse themselues at their pole before specified: so do their plaines likewise crosse in a right line, passing by the said Pole, and the center of the earth. Then producing a straight line in the magneticall plaine of London, declining from the plaine of the Horizon 71.d.51'. where the same doth crosse with the former common section of the two plaines, thereby reason shoulde the poynt Respective bee. Which intersection I finde to be from the center of the earth 1085. miles (after that rate of 60 to a degree in the equator, and 3436,4. for the Semidiameter of the Earth) and the distance of the same from the axis of the world 471 miles.

For example.

LEt the circles be as in the last demonstration, then shal BC be the distance of the pole of the Magnes from the Zenith B. And Q. the center of the Earth. QA. the axis of the worlde. QC the common section of the Magneticall playnes. BZ. the lyne of the Needles Declination crosing the said common section at R. (which is the point Respective.) QT a straight line crosing BZ. at right



right angles in X, QR. the distance of the point Respectime from the center of the earth, RS. the distance thereof from the axis. First it is requisite to knowe the quantity of the arke BC, which is thus found, as the signe of the angle ABC 11, d, 15′. hath vnto the signe of the arke AC, 25 d. 44′. So hath the signe of the angle BAC, 156, d, 30. (which is al one with the signe of the angle BAD, the difference of Longitude 23, d. 30′.) to the signe of the ark BC which is 62. d, 46′. Now as QV is to QC so is QX to QR. But the three first are knowen QV, the second right signe of the arke CT 9, d. 4′. (the difference of the Arke BT, 71, d, 50′. And BC 62. d. 46.) Then QC the Semidiameter or whole signe, and QX, the second right signe of the arke BT. Wherefore QR shall be giuen by the 4. of the sixt of Euclide.

80. 56′.	90. 0′.	18. 10′.	
QV	QC	QX	QR

If

Of the point Respectiue.

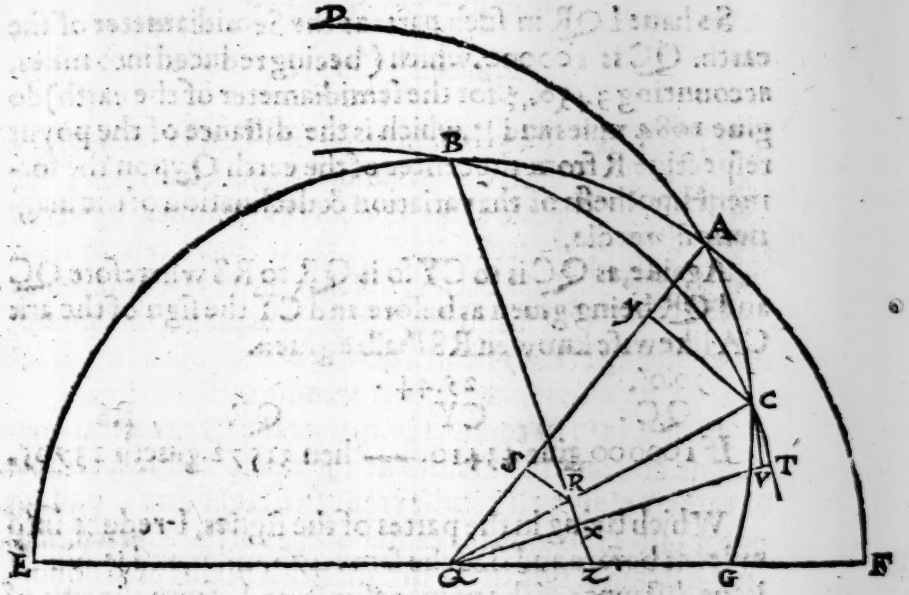
The ninth Chapter.

HAuing shewed in the former Chapter, vpon the groundes therein specified, the place of the Pole of the Magnes vpon the superficies of the earth: there resteth now to be declared of the point respectiue, wher it should be, by the new propertie found of the declining of the Needle, beeing at this place for London, 71.d.50′. as in the former treatise by R. Norman.

First it is to be considered, that as the Magnetical meridians do crosse themselues at their pole before specified: so do their plaines likewise crosse in a right line, passing by the said Pole, and the center of the earth. Then producing a straight line in the magneticall plaine of London, declining from the plaine of the Horizon 71.d.51′. where the same doth crosse with the former common section of the two plaines, thereby reason shoulde the poynt Respectiue bee. Which intersection I finde to be from the center of the earth 1085. miles (after that rate of 60 to a degree in the equator, and $3436\frac{4}{11}$. for the Semidiameter of the Earth) and the distance of the same from the axis of the world 471 miles.

For example.

LEt the circles be as in the last demonstration, then shal BC be the distance of the pole of the Magnes from the Zenith B. And Q. the center of the Earth. QA. the axis of the worlde. QC the common section of the Magneticall playnes. BZ. the lyne of the Needles Declination crosing the said common section at R. (which is the point Respectiue.) QT a straight line crosing BZ. at right



right angles in X, QR. the distance of the point Respectime from the center of the earth, RS. the distance thereof from the axis. First it is requisite to knowe the quantity of the arke BC, which is thus found, as the signe of the angle A*B*C 11.d. 15′. hath vnto the signe of the arke AC, 25 d. 44′. So hath the signe of the angle BAC. 156.d.30. (which is al one with the signe of the angle *B*AD, the difference of Longitude 23.d.30′.) to the signe of the ark BC which is 62.d.46′. Now as QV is to QC so is QX to QR. But the three first are knowen QV, the second right signe of the arke CT 9.d.4′. (the difference of the Arke BT, 71.d.50′. And BC 62.d.46.) Then QC the Semidiameter or whole signe, and QX, the second right signe of the arke *B*T. Wherefore QR shall be giuen by the 4. of the sixt of Euclide.

80.56′. 90.0′. 18.10′.

QV QC QX QR

If

If 98.750 giue 100000——then 31178. giueth 31572.

So haue I QR in such parts as the Semidiameter of the earth. QC is 100000. which (beeing reduced into miles, accounting 3436. $\frac{4}{11}$. for the semidiameter of the earth) do giue 1084 miles and $\frac{14}{11}$. which is the distance of the poynt respective R from the center of the earth Q vpon the former Hipothesis of the variation & declination of the magneticall needle,

Againe, as QC is to CY so is QR to RS wherefore QC and QR being giuen as before, and CY the sign of the ark CA likewise knowen RS shalbe giuen.

90.0′.	25.44′.		
QC	CY	QR	RS

If 100000. giue 43410.——then 31572. giueth 13705.

Which being in the partes of the signes, I reduce into miles as before and find the same 470. miles, and $\frac{17}{11}$. which is the distaunce of the point respective R from the axis of the world QA. By the former Hypothesis,

The tenth Chapter.

Of the application of the variation, to the vse of Nauigation.

Vpon the Hipothesis of ỹ pole of the Magnes on the superficies of the earth, and the point Respective in the bodye thereof, according to the former calculations, might bee inferred many pleasaunt conclusions, both for the longitude & latitude of places.

But as touching the point Respective by the declining of the Needle, seeing this is the first and onely experiment that hath beene made of it, I cannot inferre any further matter thereof, than that which I haue already set down, vntill by obseruations in other places, wee finde howe it will holde.

And

And as for the variation, if it were generally regular and certaine, as in some parte it seemeth to be: (that is to saie, from hence Westwardes to Meta Incognita, Newe-found-land, Florida, and that part of the coast of America) then might there beginen by it generall rules, commodious for the vse of Nauigation.

And by the same Hypothesis of the Pole of the magnes at 25.44′. from the Pole of the worlde, the greatest variation of the Needle in the Equinoctiall, should be (at 90.d. of Longitude) 25.44′. from North to East, and consequently the greatest variation in the Paralell of 70 d. should be (at the Longitude of 128.d.51′.) from North to East 81.d.14′. And in the meridian of 180.d. of longitude betweene the two Poles (the Pole artick I meane) & the supposed Pole of the Magnes, there should the North point of the needle or compasse respecting his own pole, shew the south, and the south point the North pole of the world.

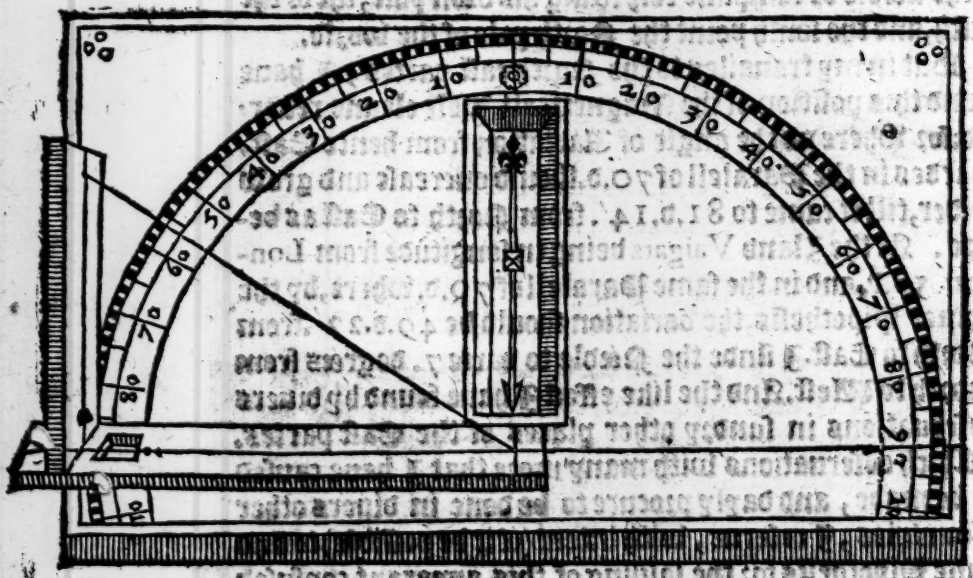
But in my trauailes to the North east partes, I haue found this position of the Magneticall Pole cleane reuersed: for where as the angle of Variation from hence Eastwardes in the Paralell of 70.d. should encrease and grow wider, till it came to 81.d.14′. from North to East as before. At the Iland Vaigats being in longitude from London. 58.d. and in the same Paralell of 70.d. where, by the former Hipothesis, the variation should be 49.d.22′. from North to East. I finde the Needle to varie 7. degrees from North to West. And the like effect I haue found by diuers obseruations in sundry other places of the East partes. Which obseruations with many more that I haue caused to be made, and daily procure to be done in diuers other Countries, I reserue, with intent (if it be possible) to finde some Hipothesis for the saluing of this apparant confused irregularitie.

At Ratisbona or Regensburg in Bauaria, being in latitude 48.d.52′. & in longitude 36.d.20′. where, by the former position of the Magneticall Pole at 25.d.44′. the varia-

Variation should be 16.d.44′. from North to East. Gerardus Mercator found the same to be onelie 11.½ as I gather by his placing of the Magneticall Pole at 16.d.22′. from the Pole artike, vppon his obseruation made at that place: which confirmeth the retrograde qualitie in the variation from hence Eastwards, as afore said.

Which strange varietie, I haue heere plainly proposed, to the end that the learned sort might consider therof, and sharpning their wits, see what probable causes & grounds they can assigne for the same. For considering it remayneth alwaies constant without alteratiõ in euery seuerall place, there is hope it may be reduced into method & rule.

A new Instrument for the Variation.



BEcause I haue founde some imperfections in the first instrument for the variation (which notwithstanding doth far excell the compasses of variation heeretofore vsed for that purpose) I haue heere set down the forme of a new

Instrument

Instrument wherein all scruple of doubts and defects that might growe by other is quite auoyded. Which beeing once exactlie placed with the needle vpon the line of south and north, will serue without remouing for a whole dates obseruation, the Index onely beeing carried about wyth the Sunne, to giue the degrees of Azimuth vpon the Instrument by the shadowe of the line thereof, and is otherwise to bee vsed according to the prescript rules of the former Instrument.

Of the inconueniences and defectes in sayling, and in description of Countries, caused by the variation of the Compasse.

The eleuenth Chapter.

IN all Sea Chartes generally, which are made without consideration of the variation, are committed great errors and confusion. For, either the partes therein contayned, are framed to agree in their latitudes by the skale thereof, & wrested from the true courses that one place beareth from another by the Compasse, or else in setting the partes to agree in their due courses, they haue placed them in false latitudes, or abridged, or ouerstretched the true distaunces betweene them.

In the Marine Plats made for Newfoundland, the course set downe from Sillie to Cape Raso is due West, which is found to be so for our common sayling Compasse, whose wiers are set ½ a point from North to East, notwithstanding Sillie being in latitude 50. d. lyttle more. Cape Raso in Newfoundland is found to bee but in 46. d. ⅔ which is 3. d. ⅓ lesse then the latitude of Sillie.

To make a shew of reformation of this error, caused by the variation and setting of the wiers in the (Compasse) or to giue a light of that difference in longitude, they

haue placed in the plat againſte that coaſt a newe ſkale of Latitude, ſome vppon the line of South and North, and ſome other haue placed the ſame vppon the line of North Northeaſt, and South Southweſt (becauſe the point of the Compaſſe ſheweth the Pole nereſt in that place) and haue furniſhed the degrees thereof agreeable to the Latytude of Cape Raſo: and by that meanes haue had a double ſcale of latitude, one for the Eaſter coaſts, the other for that Weſt. But how farre the ſame hath beene from reforming the errour, or giuing any helps to Nauigation, you may eaſily iudge.

Others, to auoyde that errour of the difference in Latitude in that voyage and courſe, haue vſed Compaſſes, whoſe wiers haue beene ſette dyrectly vnder the North poynt, and thereby ſayling Weſt from Sillie, haue fallen to the Northwardes of Cape Raſo about 50. leagues, and in latitude neere 49. d.

Some other haue vſed in the ſame voyage to place a blanke Flie vpon their ſayling compaſſe, which they haue remoued from time to time, as they haue iudged the variation hath altered: by which way, albeit they may ſeeme to keepe themſelues nearer the paralell, yet the ſame in Nauigation worketh the greateſt confuſion of all other, & therefore is to be vtterly abolished.

In our voyages from hence Eaſtwards to S. Nicholas in Ruſſia, and to the Narue in Liuonia &c. The Marine Plats of the coaſtes are deſcribed by our Common ſailing Compaſſe, with conſideration of the variations at dyuers places, whereby the true meridians reformedly ſet down, declyning from the paralell Meridians of the plat, doe neceſſarie widen Northwardes, and ſtraighten to the Southwardes, contrarie to the true forme and nature of meridians. And yet notwithſtanding, that is the beſt meanes hitherto knowen, to reforme in Plat, the errours that elſe would growe by the ſtraunge variations that way.

And

And albeit these places serue verie well for those Nauigations, yet by meanes of the variations considered, the forme of those coastes is so disforted from the ryght shape it shoulde beare, beeing truely described vppon the globe or otherwise in plaine, according to the true latitude and longitude: That whereas the Narue (beeing in Latitude 59.d.½. and in Longitude from the Meridian of London 26.d.10′.) should be from S. Nicholas 9.d.40′. in lõgitude to the Westwardes (S. Nicholas beeing in Latitude 64.d.35′. and in longitude from London 35.d.50′.) In the sailing Plat it is brought to bee in the meridian of Colmogorõd, (which is in latitude 94.d.20′. and in longitude from London 37.d.45′) which is 1.d 55. to the eastwards of the meridian of S. Nicholas.

Into the Mediterranean Sea, and in the coastes thereof, wherein great reason should be the perfectest descriptions of the worlde, for that in those partes haue bene the seates and abodes of the most famous and learned men in all ages, we see notwithstanding in the marine Plats of those partes, grosse errours commited, through want of knowledge of the variation, and the vse thereof, in which they haue not accounted of 3.4. or 5. degrées errour in the latitude of places.

But those defects of the latitudes haue bene very well reformed, by the famous and learned Gerardus Mercator (whom I honor and esteeme as the chiefe Cosmographer of this time) in his vniuersall Map, which though hee haue made with sailing lines, & dedicated to the vse of Seamẽ, yet for want of consideration of the variation, the same is more fit for such to beholde, as study in Cosmographie, by reading authors vppon the lande, then to be vsed in Nauigation at the sea.

There is also in the same vniuersall Mappe, and likewise in all other moderne Maps of the North parts of Europe, a great fault, by placing two Wardhouses distaunt one from the other aboue 20 d. in longitude, whereas

indeede they are but one thing, and no such distaunce betweene them. This error hath growen by taking Wardhouse, and the Sea costes, from thence to S. Nicolas Vaigats, and the Ob &c. out of the Map of of that worthy trauailer, M. Anthonie Ienkinsons his iourney to Boghar & Persia, &c. In the which I placed that border of the Sea coast, and for some causes went no further Westwardes in that description, then Wardhouse which is in latitude 70.d.; and in longitude from London 29. d. Wherefore to accomplish the whole border of that coast, hee was forced to seeke some other description to ioyne with it, and toke as appeareth the Map of Olaus Magnus of the north Countries, wherein he found likewise Wardhouse, but falsely placed in latitude about 19.d. too much, & in longitude as much too little, the which, although he might take to be the same specified in Maister Ienkinsons Map, yet he was constrained to seperate them the said distaunce of 20.d. in longitude (or to leaue there so much superfluous rome) otherwise he should haue thrust the South partes of those Countries togeather, and confounded the whole description.

And albeit he had had the entire sailing Plat, that weere vse for those parts, yet if hee had not knowen the secret effect of the Variation in the making thereof, he might haue fallen into the like absurditie or worse. But of those coasts and of the inward partes of the Countries, Russia, Muscouia, &c. I haue made a perfect Plat and description, by mine owne experience in sundrie voyages and trauailes, both by Sea and Land, too and fro in those parts, which I gaue to her Maiestie in Anno 1578.

Besides these and like imperfections proceeding of the Variation, there is yet another inconuenience, which oftentimes encreaseth the former errours, and that is, the diuers placing of the wiers, fixed to the Flie of the Compas.

This varietie of setting the wiers, hath caused great confu-

confusion in Nauigation, and in other accountes of Sea causes: for when it is said, that from such a head land, to such a place, in such a course, or at such a place the Wynde vpon suche a point of the Compasse maketh the full Sea, it is requisit to bee demaunded, by what Compasse the obseruation was made: whereas if the wiers had not bene altered from the North poynt of the Flie, which I wishe had neuer bene any where) these doubtes had beene auoyded.

It behoueth therefore all men that will make Hydrographicall descriptions for the vse of sailing, to haue speciall regarde of the Compasse by which these obseruations are made, and if they collecte notes made by sundry Compasses of diuerse sortes, they ought to reduce all the varieties vnto some one certaine, and to giue notice of the same in their Plat: And not to make a confused mingle mangle by ioyning togeather all varieties of obseruations, notes, and reports, as the Portingales and Spaniards haue done, in compounding these North partes of the worlde, with their owne discoueries, without consideration of the diuers sortes of the seueral compasses by which they were made.

Also it importeth all maisters, Pilots, and others by what name soeuer, that shall giue directions in Nauigation, to looke circumspectly to the setting of the wiers of the Compasse by which they shall sayle, that the same Compasse be correspondent, to the lines of the Sea Carde that they shall vse: that is to say, that it be of the same set for the variation, that the Compasse was of, by which the carde was made.

And seeing wee haue in this our countrey, acquainted our selues commonly in our obseruations and Nauygations, with the Compasse, whose wiers are set at ½. a point from North to East, I meane in the descriptions that I shall make to applie the same agreeable to the said Compasse and would vse the like without alteration (and al-

so the straight lines in Sea Cards) if I should saile round about the worlde to make the description thereof, but alway with regarde of the seueral variations of euery place, where the same should be obserued.

Of the Instruments and rules in Nauigation.

The Twelfe Chapter.

AMongst the rules and Instrumentes for Nauigation, all such are vaine & to small purpose, wherin the true meridian is presupposed to be giuen by the Magneticall Needle, without due consideration of the Variation, for that they are all grounded vpon false suppositions. Heere by it commeth to passe that one Michael Coignet of Antwerp, in his New instruction (as hee tearmeth it) of the moste excellent and necessarye points of Nauigation, wherin he sheweth the making and vse of a Nauticall Hemisphere, which he preferreth before all other Sea Instruments, is very childishly abused. For whereas he pretendeth by it, to giue the eleuation of the Pole, and the houre and instant of the time of the daie, by any one obseruation in any place: besides that, it is of all other that hath hetherto beene vsed at Sea, the moste tedious and vnfit for that purpose: it is also by reason of the variation not considered, meere false and erroneous. For the true Meridian (which is the grounde of his purpose, as farre to seeke as the thinge hee promiseth to giue by the same. The like may be sayd of all other instrumentes made vppon the same grounde, whether they serue for the sea or land.

The same author in the 4. Chapter of his booke, entreating of sailing vpon the pointes of the Compasse, sayth, that in sayling South or North he shall passe by the poles

of

of the world, and keepe vnder one Meridian, till hee come to the place from whence he first departed. And vpon the points of East and West out of the Equinoctiall, hee shall saile vnder a Paralell, till hee returne to the place from whence he went. But in sailing vpon the point of North-East, he shall describe a spirall line inclining by little and little towards the Pole, as in his demonstration thereof in the same Chapter appeareth. But for want of due consideration of the variation, his rules, reasons, and demonstrations, and such others hitherto giuen for like purposes are friuolous and false.

For if he direct his sailing by the Compasse (as of necessitie he must, beeing the onelie Instrument for that purpose) it is manifest, that whether hee saile North or South, East or West, or by what other point so euer, the Compasse not respecting alwaies the Pole of the World, as hee supposeth, but some other pointe or points distaunt from the same, shall lead him accordinglie, whereby hee shall neither keepe vnder one Meridian, nor vnder one paralell of latitude, neither make such a spirall line to the Pole of the worlde, as he demonstrateth. His fault in setting downe those rules is so much the greater, in that hee acknowledgeth in the Chapter next before the variation at Antwerpe, to be about 9. d. from North to East according to Mercators position, of the Magnetical Pole, which he also confirmeth by his owne experience.

But it seemeth he hath followed that excellent Mathematician Petrus Nonius, especially concerning the sailing vpon the points of East and West. For he, in his first booke of the rules and Instruments of Nauigation, endeuoreth himselfe to proue and demonstrate, that in sailing East or West out of the Equinoctiall, the course is performed by peeces of great circles, and yet describeth a paralell. But howe that maye stande with the principles of Geometrie, I referre the iudgement to the expert Mathematicians, for it is like as a circle shoulde bee

made of straight lines, which is impossible.

It appeareth in the discourse that hee hath made of these matters, that hee had not a right iudgement of the nature of the Compasse in sailing (admitting the same to shew the Pols without Variation) for if he had, he would neuer haue entered in such a Labyrinth as he did. But hee thought it a great absurditie that the Compasse in euerye Horizon, should shew the Meridian & Poles of the worlde by the points of North and South, and by the pointes of East and West, to shewe in the Horizon the verticall and Equinoctiall East and West, (beeing a great circle) and yet in sailing East or West, except in the Equinoctiall, it should performe but a paralell.

But it is to bee vnderstoode, that albeit the points or lines of the Compasse do alwaies in euery Horizon represent great circles in the Heauens, the pointes of South and North the Meridian, and the points of East and west the verticall circle of East and West, each crossing other at right angles, and likewise of the pointes. (The reason whereof is, because the Compasse lieth euery where leuel with the Horizon, so as a perpendicall line descendyng from the center thereof at right angles with the playne of the same, will alwaies fall vppon the center of the earth, and consequently bee the Semidiameter of a great circle) so that wheresoeuer the Compasse bee caried, these circles are supposed to bee carried about with it, and the viewe of euerie thing in the Horizon, represented by the poyntes thereof, is likewise in great circles: Yet in sailing by the Compasse, the points of South and North onely, describe great circles generallie, which are the Meridians, and the pointes of East and West, describe a great circle in the Equinoctiall onelie: in all other places out of the Equinoctiall, they describe but Paralels. And the sailing vppon anie other point of the Compasse from anye place, describeth a spirall line, according to the angle it maketh with the Meridian. And heereby in sailing vppon the

points

points of East or West, out of the Equinoctial,) the North point alwaies respecting the pole (the course perfourmeth a Paralell, according to the distaunce of the center of the Compasse from the pole. The manner thereof you may perceiue by fastning a small thrid or Virginall wier at the Pole of a Globe, or center of a circle, which shall represent a moueable Meridian to be carried about the globe or circle, and fire vpon the same, a small Flie of a Compasse, so as the line of South and North be answerable to the thrid or wier, and the North point thereby alwaies respect the North pole: then in turning the thrid about the Globe or circle, vpon the Pole or center, if the center of the Flie be out of the equinoctiall, (betweene it and the Pole) albeit the pointes of East and West, crossing the same line and moueable meridian at right angles, doe shewe the Aertical East and West vppon the Globe, which is a great circle, yet in carring the same Flie vpon the thrid or moueable meridian about the pole or center, you shall by the center of the same Flie describe but a Paralell according to the distaunce thereof from the Pole of the Globe, or center of the circle not vnlike the circular motion of a horse drawing in a Mil, who though he loke forth straight in a right line, yet being fastned to the beame of the Mill, is forced to make his course in a circle, whose semidiameter is the length of the beam contained betweene the horse and the center of your mill or milpost.

And as in the Equinoctiall, the line of South and North in the Compasse (by supposition representing the Meridian) is paralell to the Axis of the earth, (which is the common section of all the Meridian plaines,) and the line of East and West, crossing the same Axis of right angles, representeth the vertical East and West, which is the Equinoctiall, imagining to discend from the center of the Compasse a line, to fall perpendicularlie, and at right angles with the Axis of the worlde (which shalbee at the center of the earth) and in sailing East or West by the com-

passe

passe, the imagined perpendicular line being caried about with the same (making alwaies right angles with the axis) shall describe the plaine of the Equinoctiall, Equidistant from the Poles of the worlde, and at right angles with the axis: and the point of the same line at the center of the Compasse, the circumference of the Equinoctiall, vpon the superficies of the Sea: so beeing from the Equinoctiall on either side, imagining the line of south and North in your Compasse, to represent alwaies the Axis of the Worlde, and to lie Paralell with it, the line of East and West must crosse the same axis alwayes at right angles: And supposing a line to fall from the center of your Compasse to the axis of the worlde, making right angles with the same axis. In sayling East or West, that imagined line beeing carried about with the Compasse (alwaies at right angles with the axis) shall describe the plaine of a paralell, equidistant to the plaine of the Equinoctiall, and the point thereof at the center of the Compasse, the circumference of the paralell vpon the superficies of the sea: which Paralell should be represented by the points of East & West of the compasse, if the line of south and North of the same, were Paralell to the axis of the Poles, as was supposed, but it is not. And therefore, as they decline one from ỹ other, so doth the verticall circle of East and West shewed by the Compasse, decline from the paralell circle euerie where.

The angle of which declination is alwaies equall to the latitude of the place, or distaunce of the Paralell from the equinoctiall.

But as I haue already sufficiently declared, the compasse sheweth not alwaies the Pole of the worlde, but varieth from the same diuersely, and in sailing describeth circles accordingly. Which thing, if Petrus Nonius and the rest that haue written of Nauigation, had ioyntly considered in the tractation of their rules and Instrumentes, then might they haue beene more auaileable to the vse of

Naui-

Nauigation, but they perceiuing the difficultye of the thing, and that if they had dealt therewith, it would haue vtterlie ouer-whelmed their former plaucible conceites, with Pedro de Medina (who as it appeareth hauing some small suspition of the matter, reasoneth very clarkly, that it is not necessaris that such an absurditie as the Variation, should bee admytted in such an excellent art as Nauigation is) they haue all thought best to passe it ouer with silence. But I hope such as intend hereafter to write of Nauigation, will either frame their rules, precepts, and instruments, with regard of the Variation, as herein I haue shewed, or else ease themselues of that trauaile, for as good none, as vnprofitable.

FINIS.

may 31:1731. the ✱ mer altitude by obser
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22°:59: the Lat therefore 52°:44'. - - - - - -
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Decl. 23 07	Decl. 23 06	Decl. 23 09
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Lat 37 09	Com lat 37·09	Com lat 37 05
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these Dec. of the ☉ are taken out of gellibr
done in the year 1690. for may 31:1731. bu
the upper Dec. is taken out of the part of
book entituld the regiment for the sea.

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The Hearty

Aug^st: 23: 1738: Being the Second year after Bissextile Observed for the Lat^d of Lynn

the ☉s: Merid^n alt. = 45:00
the ☉s: Declin that day = 07:48
90 00
ht. Equator. 37:12
Lat^d = 52:48 Lynn

Otherwise. add the zenith distance, and Declin for the day of observation if it is between Mar and Sep^br: but if it is between Sep^br. and Mar = sub the Declination from the zenith Distance and the remainder is the lat of the place: as for example. in the observation above y^e the meridian altitude = 45°:00'. therefore the zenith Distance the same, and the Suns Dec^t 7°:48': which added together is 52°:48'. the Lat Sought. but had the observation been made On Dec^br 31: und the meridian altitude found 15°:16'. and Declination 21°:56': then the zenith Distance. would have been: 74°:44': and the Declination substracted leves the Latitude as under

the ☉s merd altitude. 15°:16':
then the ☉s zenith Distance. 74:44
the ☉s Declination sub. 21:56
Lat^d. 52:48: Lynn

William: Barlow Poggidett